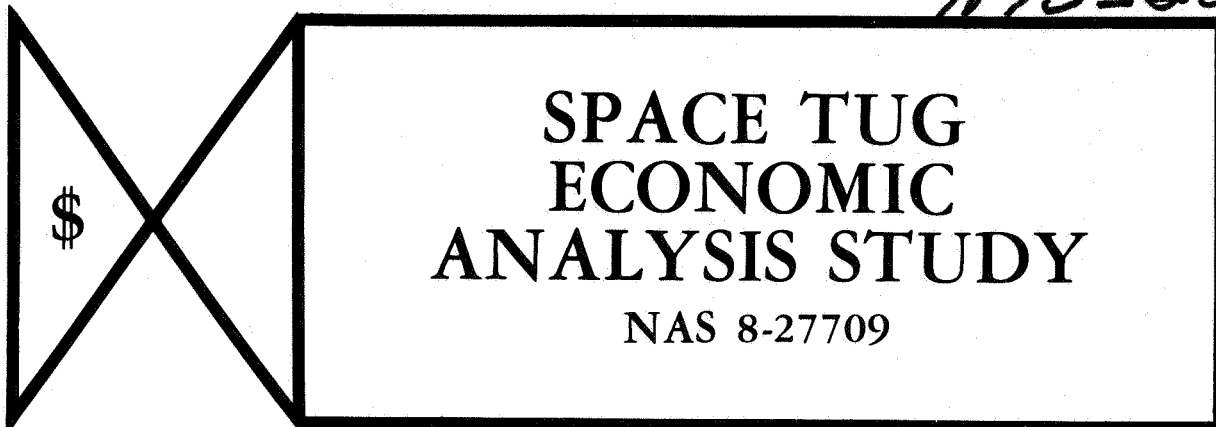


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FINAL REPORT

DR MA-04

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VOLUME II: TUG CONCEPTS ANALYSIS

APPENDIX - TUG DESIGN & PERFORMANCE DATA BASE

Prepared for

National Aeronautics & Space Administration

George C. Marshall Space Flight Center

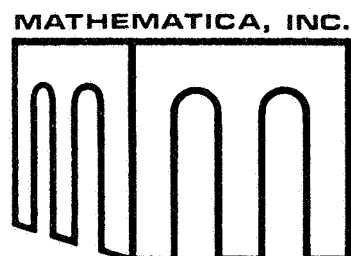
Lockheed Missiles & Space Company, Inc.

Sunnyvale, California

and

Mathematica Inc.

Princeton, New Jersey



**SPACE TUG
ECONOMIC ANALYSIS STUDY**

FINAL REPORT

DR MA-04

May 1972

VOLUME II: TUG CONCEPTS ANALYSIS

Appendix: Tug Design and Performance Data Base

Prepared For

National Aeronautics and Space Administration

Marshall Space Flight Center

Prepared By

**Lockheed Missiles & Space Company, Inc.,
Sunnyvale, California**

and

**Mathematica, Inc.
Princeton, New Jersey**

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2-1	Roadmap of Design Data in Chapter 2	2-2
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FOREWORD

This report summarizes work accomplished under the Space Tug Economic Analysis Study on Contract NAS8-27709. This study was performed for the NASA Marshall Space Flight Center by Lockheed Missiles & Space Company, Inc. of Sunnyvale, California, and Mathematica, Inc. of Princeton, New Jersey. The period of technical performance was nine months, starting July 26, 1971.

The NASA Contracting Officer's Representatives for this program were Lieutenant Commander William C. Stilwell (USN) and Mr. Richard L. Klan. The study team was led by Mr. Charles V. Hopkins of Lockheed and Dr. Edward Greenblat of Mathematica. Task leaders on the Lockheed team were as follows:

John P. Skratt	-	Data Integration and Interpretation
William T. Eaton	-	Payload Data and Payload Effects Analysis
Richard T. Parmley	-	Tug Definition

Other key team members included:

Anthony G. Tuffo	-	Data Mechanization and Evaluation
Zoe A. Taulbee	-	Computer Programming
Jolanta B. Forsyth	-	Payload Costs and Benefits; Tug Cost Model
Kenneth J. Lush	-	Program Costing Logic

This report is organized as follows:

- Volume I - Executive Summary
- Volume II - Tug Concepts Analysis
 - Part 1: Overall Approach and Data Generation
 - Part 2: Economic Analysis
 - Appendix: Tug Design and Performance Data Base
- Volume III - Cost Estimates

Volume II contains detailed discussions of the methods used to perform this study, and the major findings that have resulted. For convenience Volume II has been further divided into three parts. This Appendix supplements the results presented in the first two parts by documenting the detailed Tug design and performance information that forms part of the Tug data base.

Chapter 1

INTRODUCTION

A sizeable data base of Space Tug vehicle characteristics, costs, and performance capabilities was generated as a basis from which to compare concepts on this study. This Appendix to Volume II is a compendium of the detailed design and performance information from the data base. Comparable cost data are incorporated into a separate volume as specified in Data Requirement Description number MA-04; the cost volume is Volume III of the final report.

The design data are parametric across a range of reusable Space Tug sizes, whereas the performance curves were generated for selected point designs of expendable orbit injection stages and reusable Tugs. The Appendix is divided into two principal chapters. Chapter 2 contains the design data and Chapter 3 presents the performance data.

Chapter 2

REUSABLE TUG DESIGN DATA

This chapter presents parametric design data on reusable ground-based Space Tug concepts developed during the study. As explained at length in Part 1 of Volume II, the reusable Tugs were defined using a set of design estimating relationships (DERs). These relationships, extrapolated from Lockheed-generated point designs for the Space Tug, take the form of equations that characterize vehicle dimensions and weights down to major assembly level; the equations relate Tug design concept and propellant weight and type to specific parameters of interest. The DERs are automated in the Lockheed Space Transportation Analysis Routine (STAR) computer program which synthesizes weight statements and dimensional data across a range of propellant loadings from 20,000 to 70,000 pounds.

Chapter 2 comprises graphs of key Tug parameters; these graphs were plotted directly by computer. Information is presented in a data book format with minimum text. The sequence of Tug concepts presented in this chapter is as follows:

- LO_2/LH_2 Single Stage
- LF_2/LH_2 Single Stage
- FLOX/CH_4 Single Stage
- LO_2/LH_2 Drop Tanks (for Stage-and-one-half configurations)

To help locate data in Chapter 2, a roadmap matrix of Tug concepts and design data has been generated. This matrix, presented as Table 2-1, lists the figure references for all design graphs in Chapter 2.

Table 2-1 ROADMAP OF DESIGN DATA IN CHAPTER 2
(All References to Figure Numbers)

	LO ₂ /LH ₂		LF ₂ /LH ₂		FLOX/CH ₄		LO ₂ /LH ₂	
	Reusable	Expendable	Reusable	Expendable	Reusable	Expendable	Reusable	Drop Tanks
Structures Weight	2-1	2-19	2-30	2-48	2-58	2-76	2-86	
Thermal Protection System Weight	2-2	2-20	2-31	2-49	2-59	2-77	2-87	
Propulsion System Weight	2-3	2-21	2-32	2-50	2-60	2-78	2-88	
Avionics and Electrical-Power System Weights	2-4	2-22	2-33	2-51	2-61	2-79	N/A	
Nonusable Fluid Weights	2-5	2-23	2-34	2-52	2-62	2-80	2-89	
Nonimpulse Consumable Fluid Weights	2-6	2-24	2-35	2-53	2-63	2-81	N/A	
Total Stage Burnout Weight	2-7	2-25	2-36	2-54	2-64	2-82	2-90	
Tug Gross Weight	2-8	2-26	2-37	2-55	2-65	2-83	N/A	
Mass Fraction Based on Gross Stage Weight	2-9	2-27	2-38	2-56	2-66	2-84	-	
Mass Fraction Based on Burnout Weight and Impulse Propellant	2-10	2-28	2-39	2-57	2-67	2-85	-	
Oxidizer Tank Dimensions	2-11	2-11	2-40	2-40	2-68	2-68	-	
Oxidizer Tank Volume	2-12	2-12	2-41	2-41	2-69	2-69	-	
Oxidizer Tank Area	2-13	2-13	2-42	2-42	2-70	2-70	-	
Fuel Tank Dimensions	2-14	2-14	2-43	2-43	2-71	2-71	-	
Fuel Tank Volume	2-15	2-15	2-44	2-44	2-72	2-72	-	
Fuel Tank Area	2-16	2-16	2-45	2-45	2-73	2-73	-	
Stage External Surface Area	2-17	2-29	2-46	2-46	2-74	2-74	-	
Stage Overall Length	2-18	2-18	2-47	2-47	2-75	2-75	-	

STRUCTURE

REUSEABLE MODE

LOX HYDROGEN PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

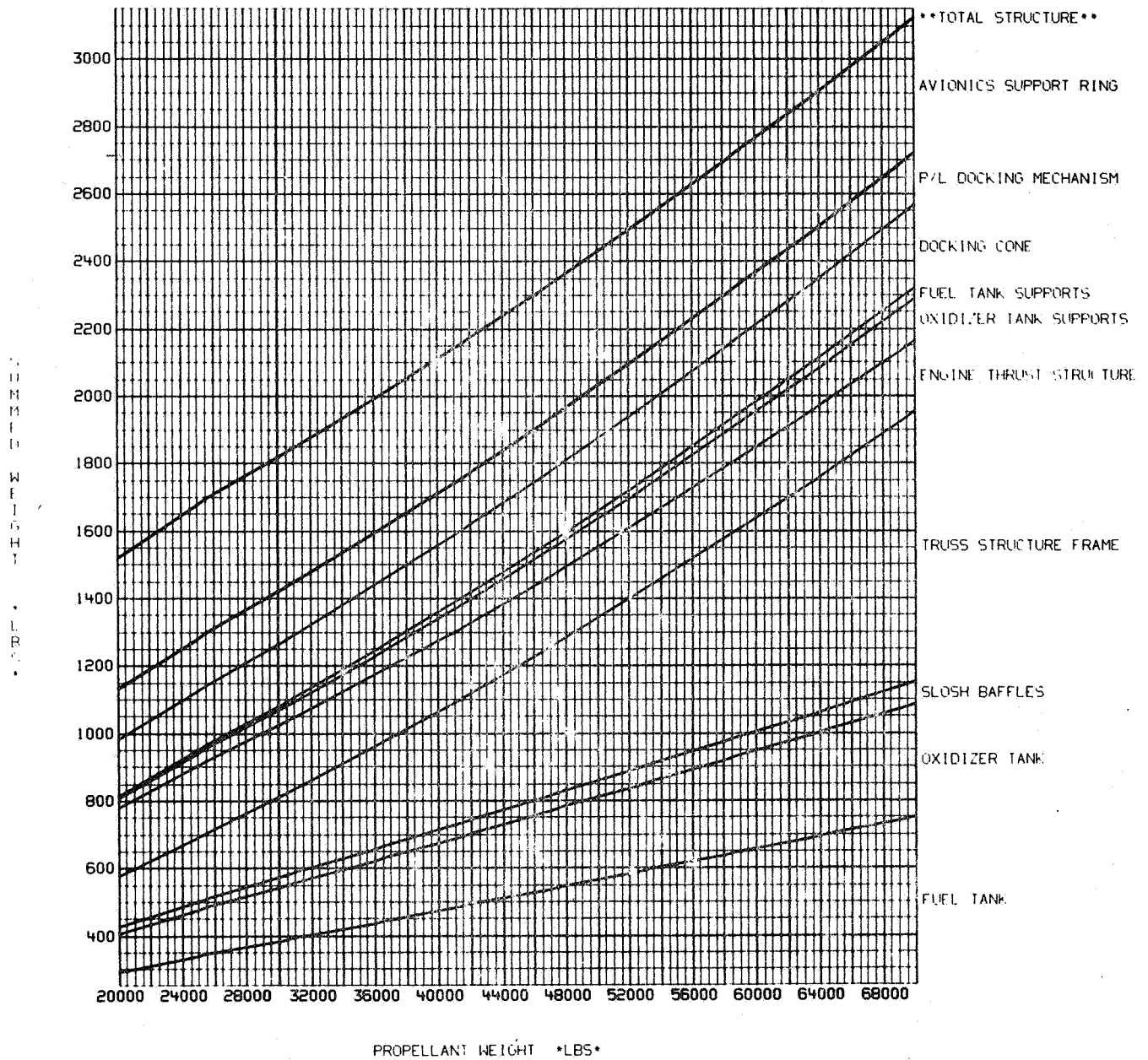


Figure 2-1

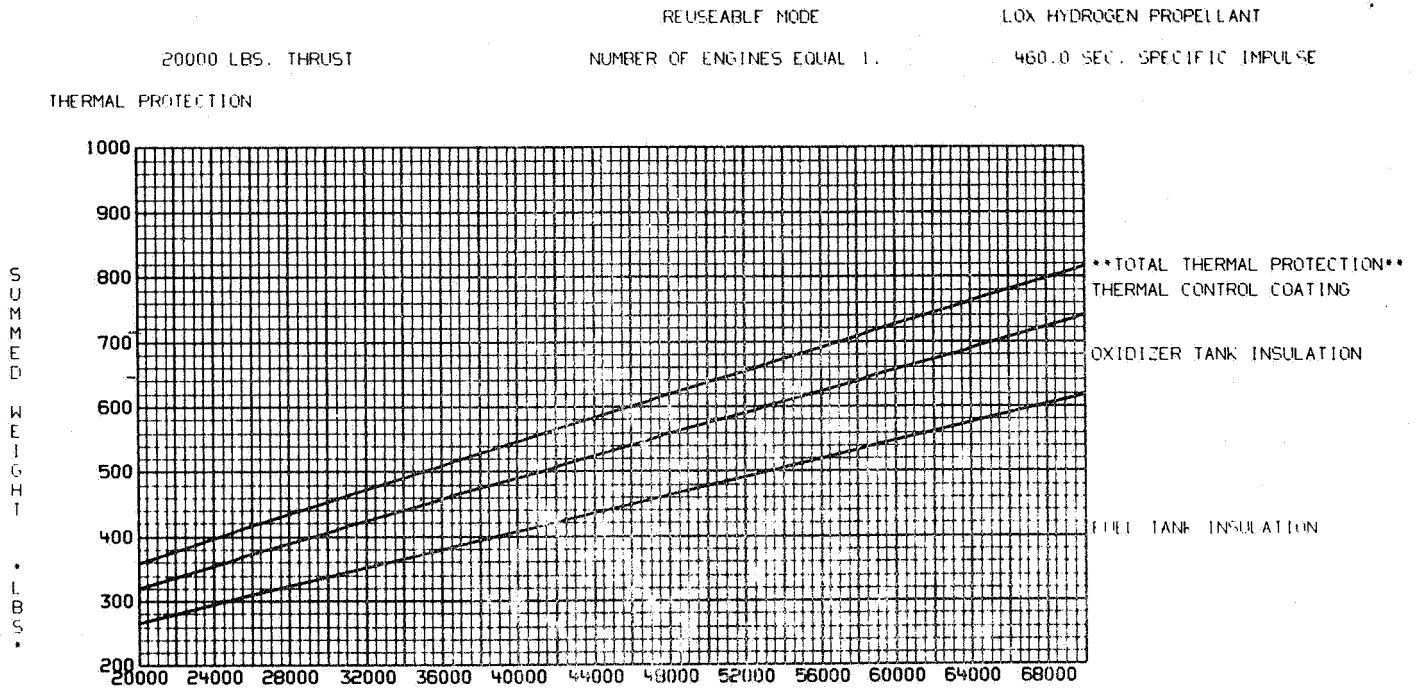


Figure 2-2

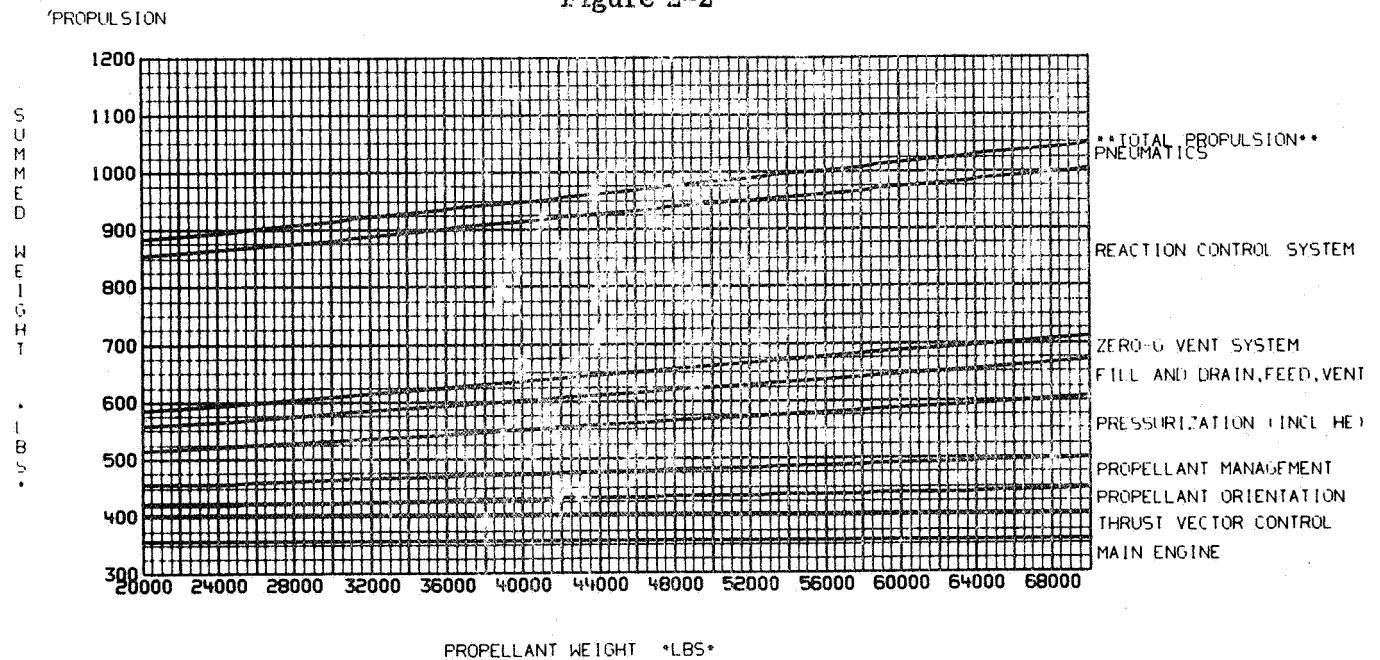


Figure 2-3

AVIONICS AND ELECTRICAL POWER

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

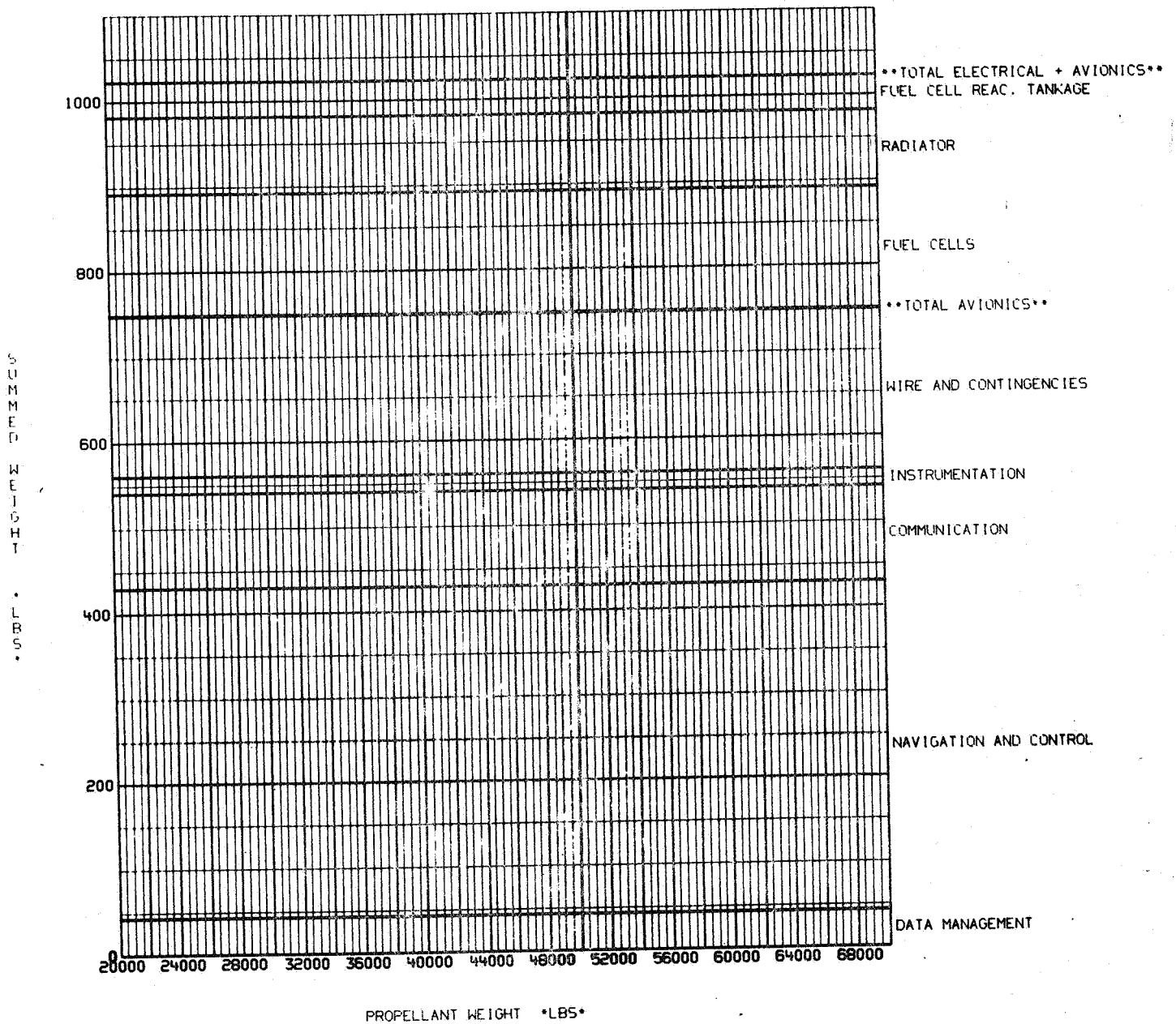


Figure 2-4

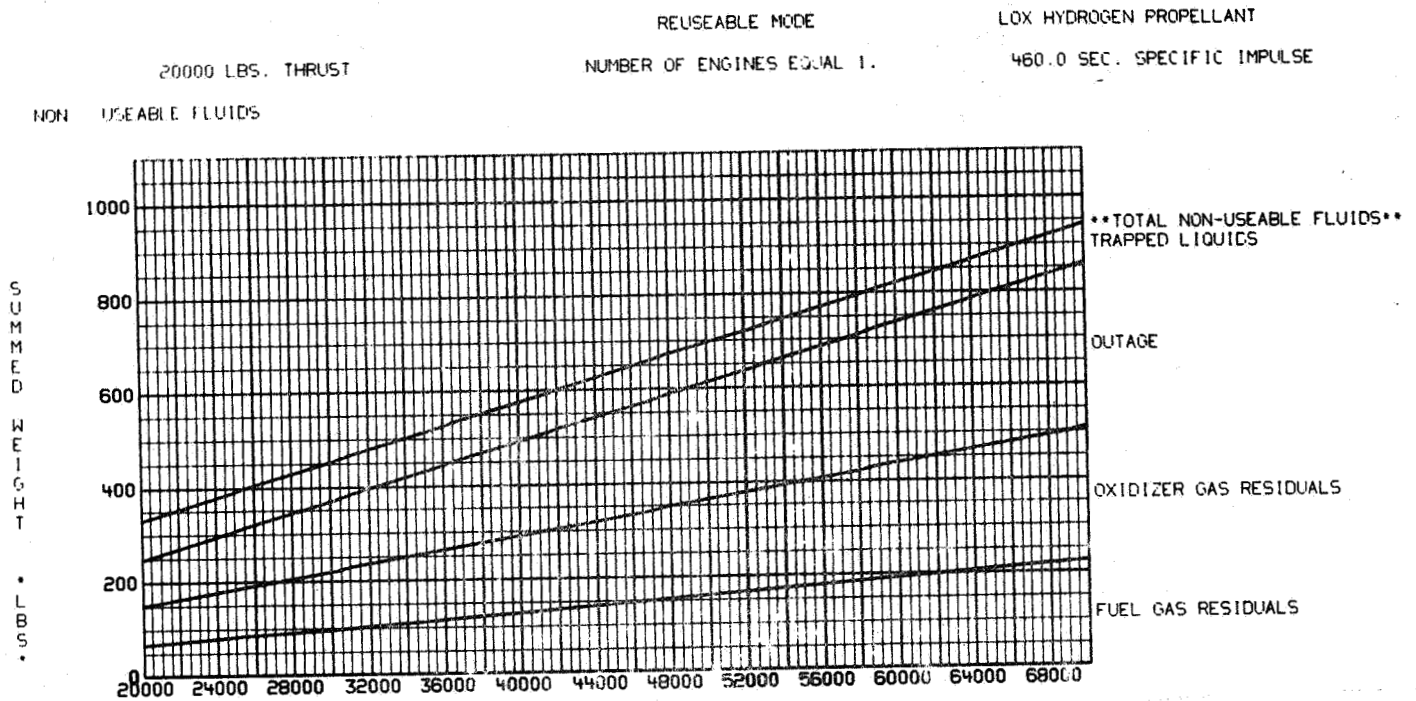


Figure 2-5

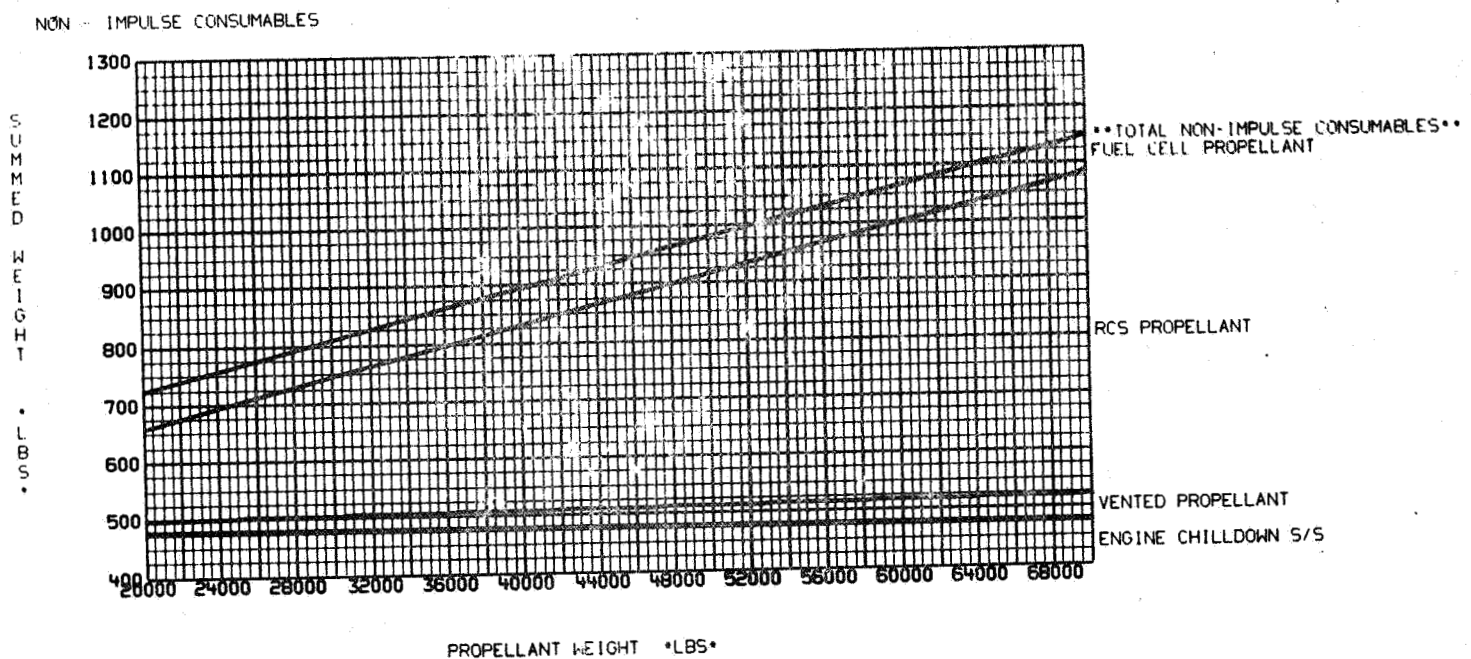


Figure 2-6

ADVANCED TUG SYSTEM WEIGHTS

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

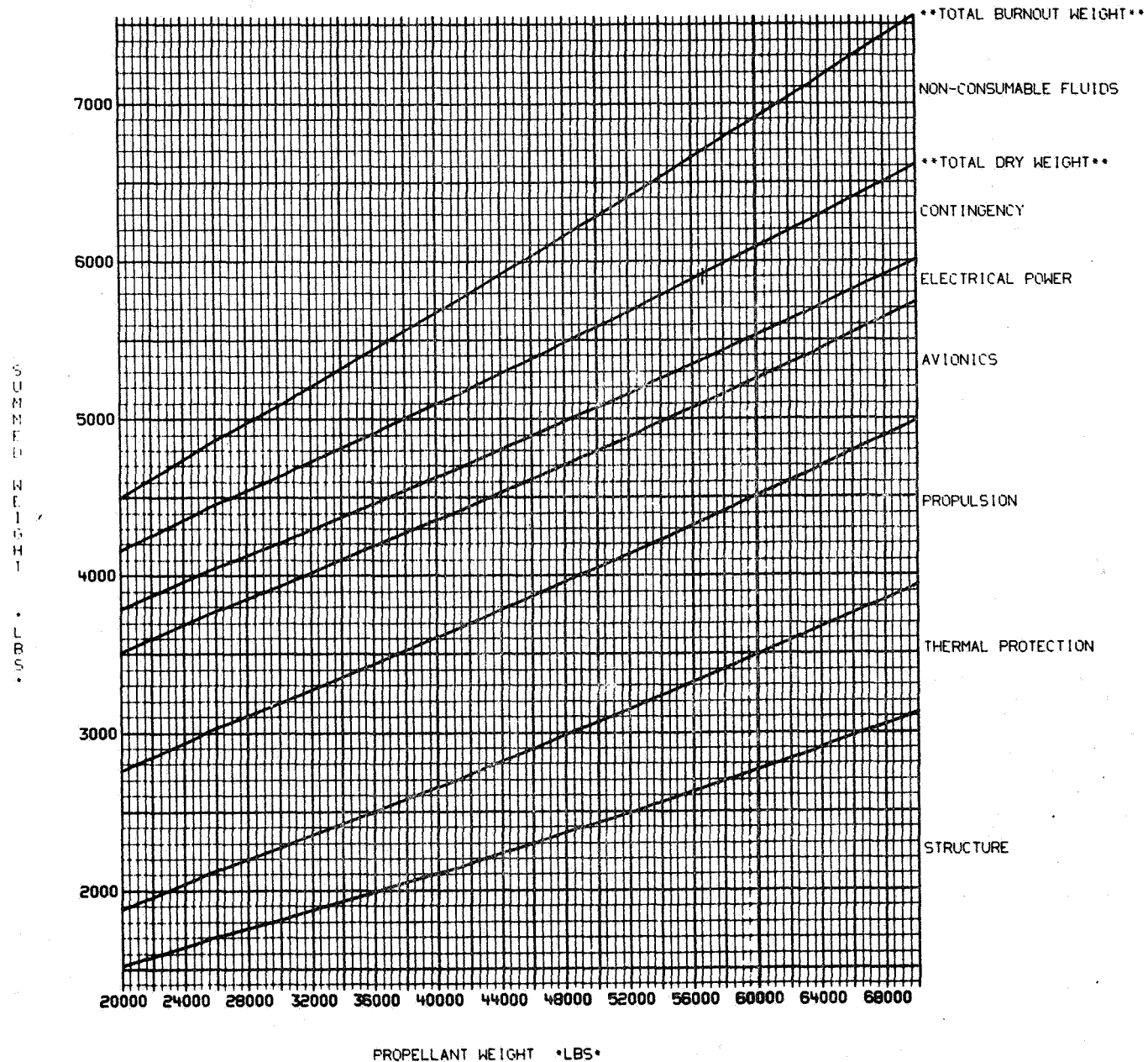


Figure 2-7

BURNOUT AND TOTAL GROSS STAGE WEIGHT

REUSEABLE MODE

LOX HYDROGEN PROPELLANT

70000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

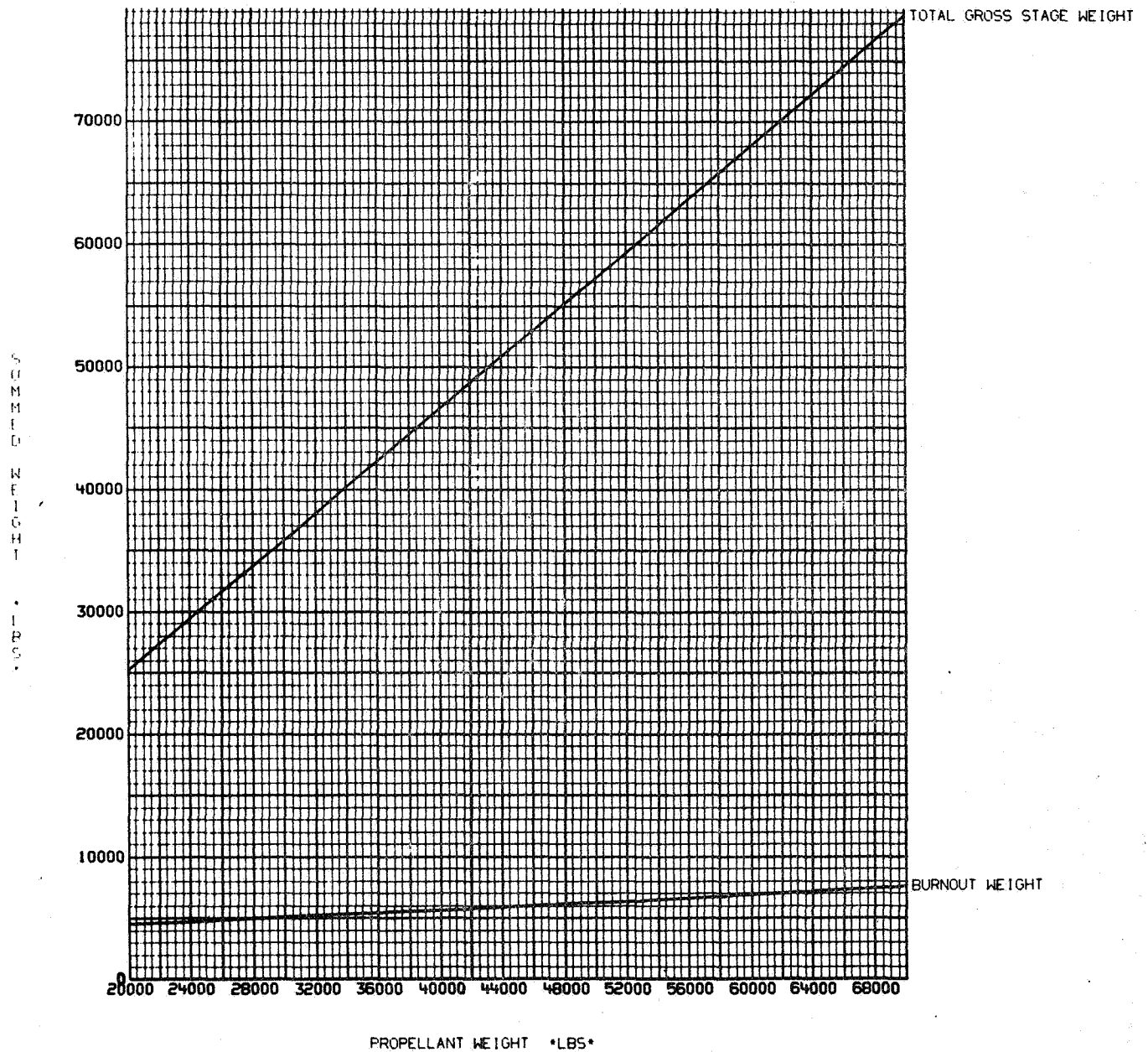


Figure 2-8

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

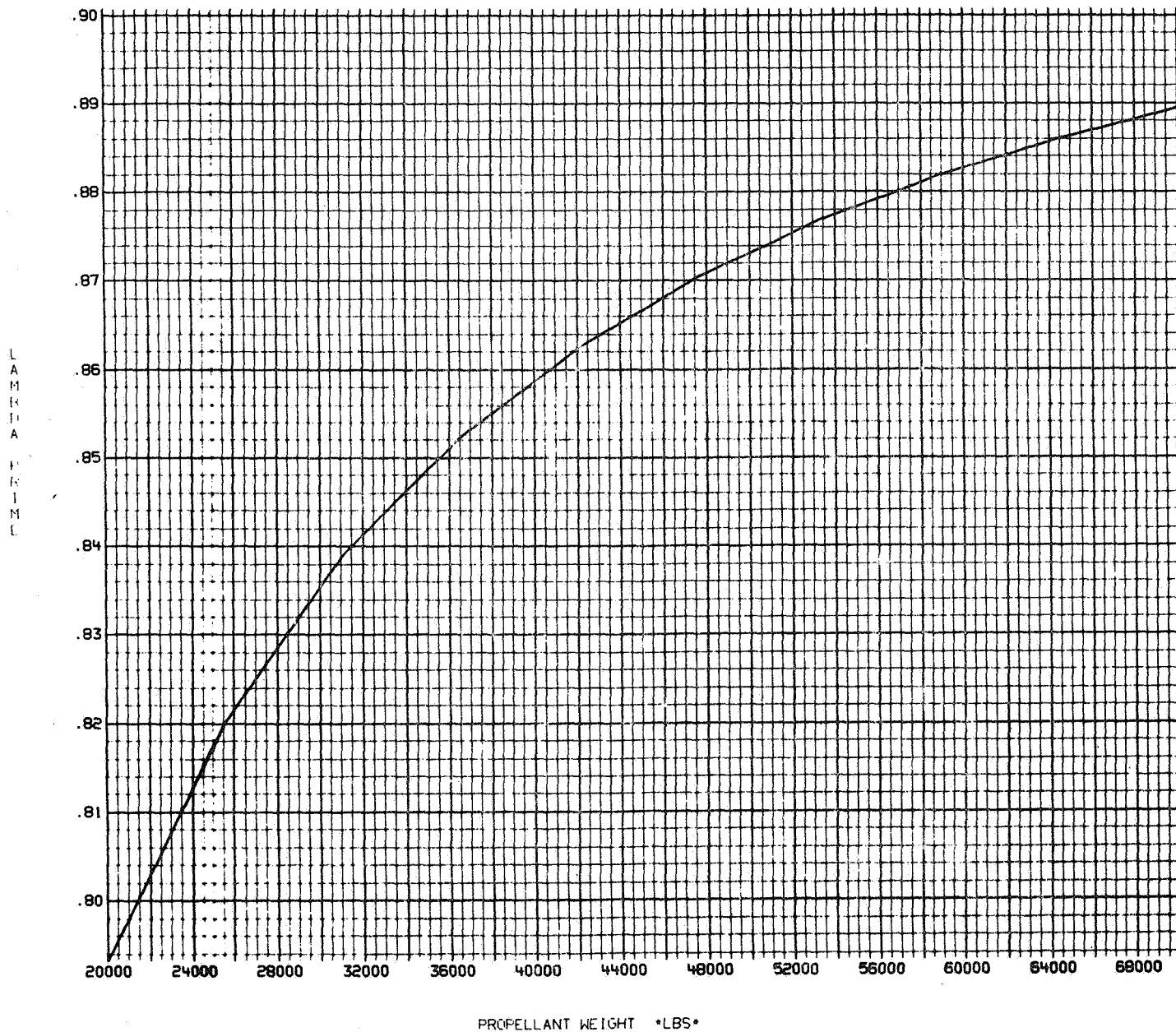


Figure 2-9

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP. REUSEABLE MODE LOX HYDROGEN PROPELLANT
20000 LBS. THRUST NUMBER OF ENGINES EQUAL 1. 460.0 SEC. SPECIFIC IMPULSE

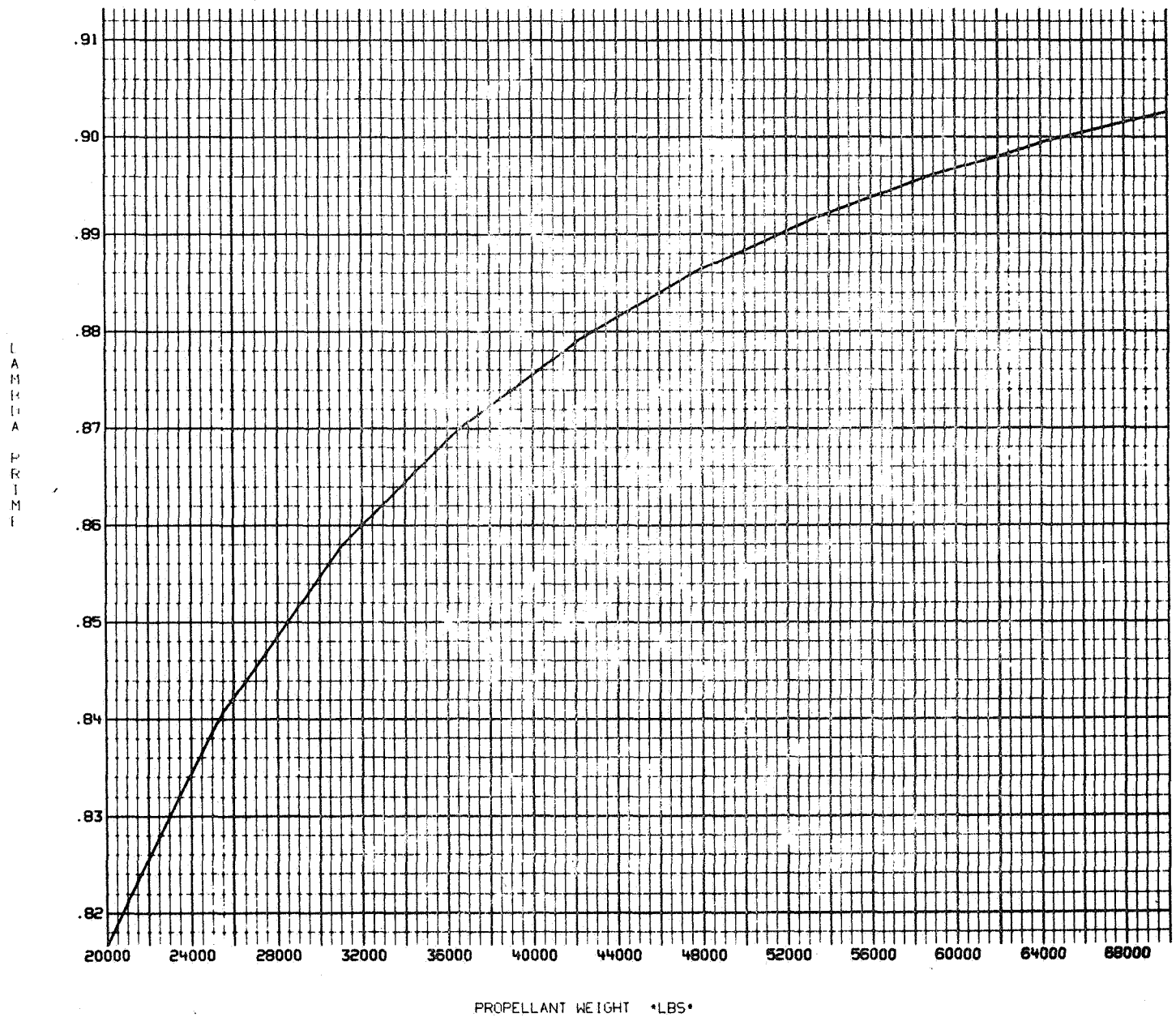


Figure 2-10

OXIDIZER TANK

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LON HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

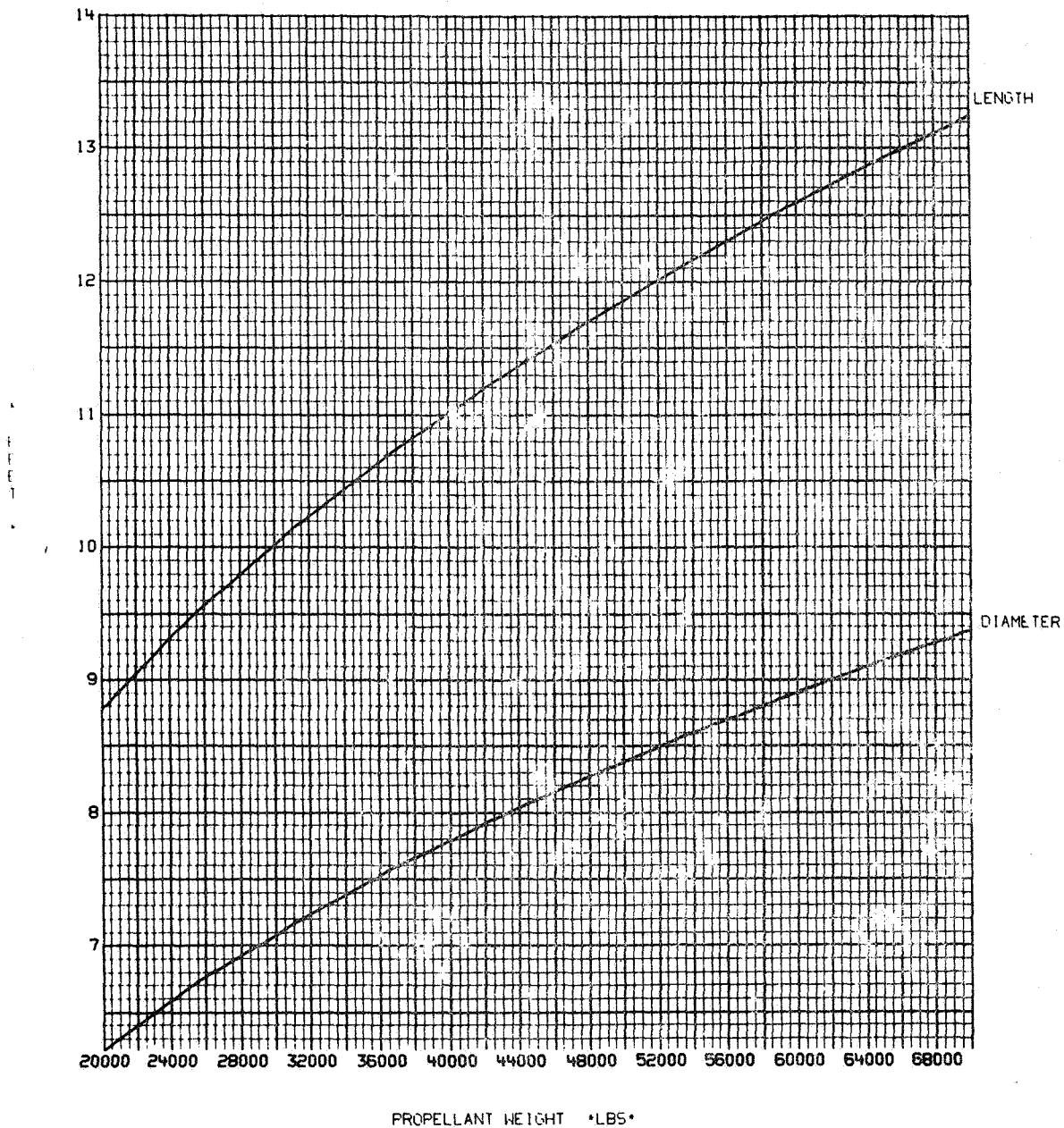


Figure 2-11

OXIDIZER TANK

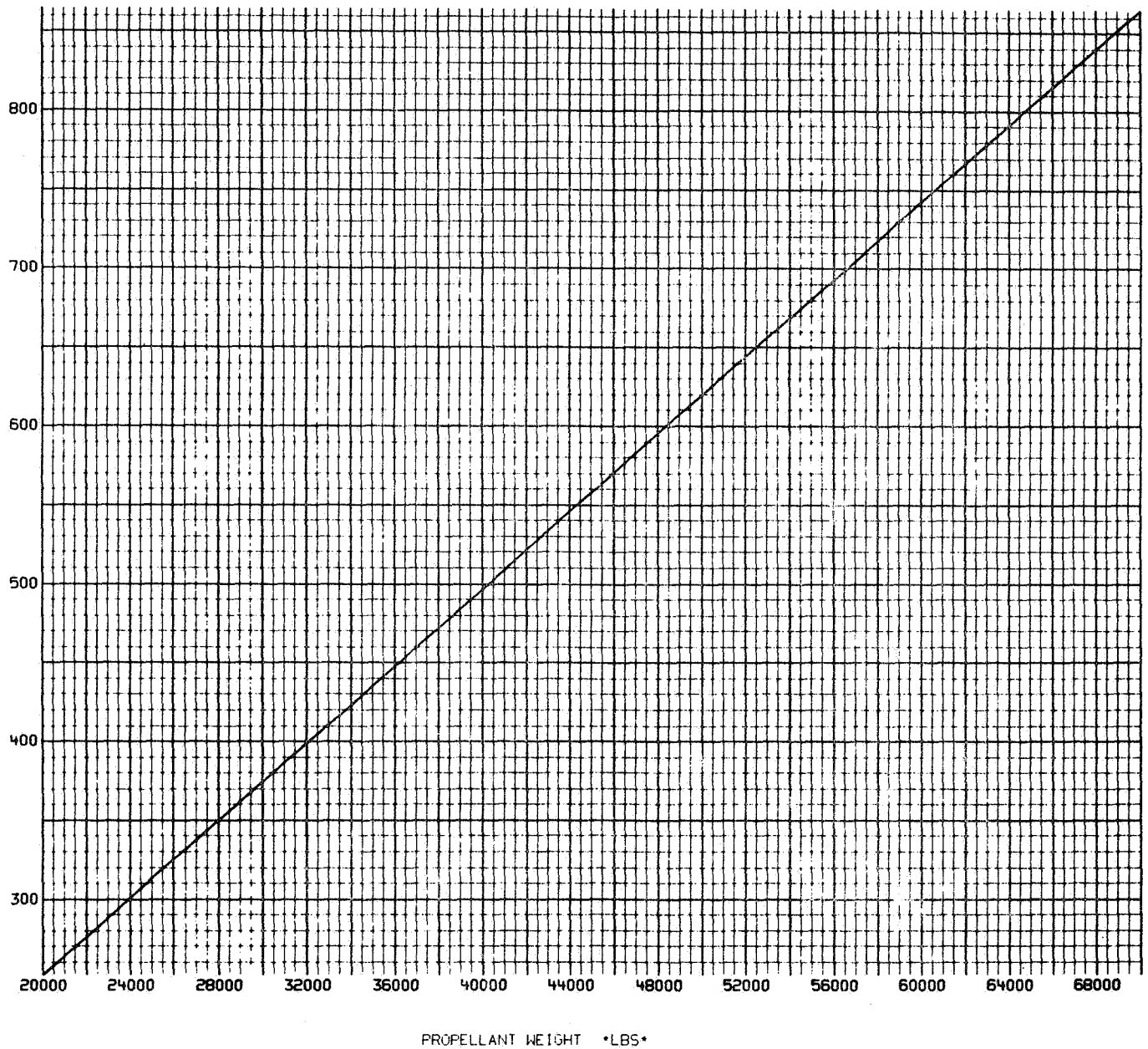
20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE



PROPELLANT WEIGHT *LBS*

Figure 2-12

OXIDIZER TANK

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES FOUR (4)

LOX HYDROGEN PROPELLANT

450.0 SEC. SPECIFIC IMPULSE

APPLA
S
E
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C
A

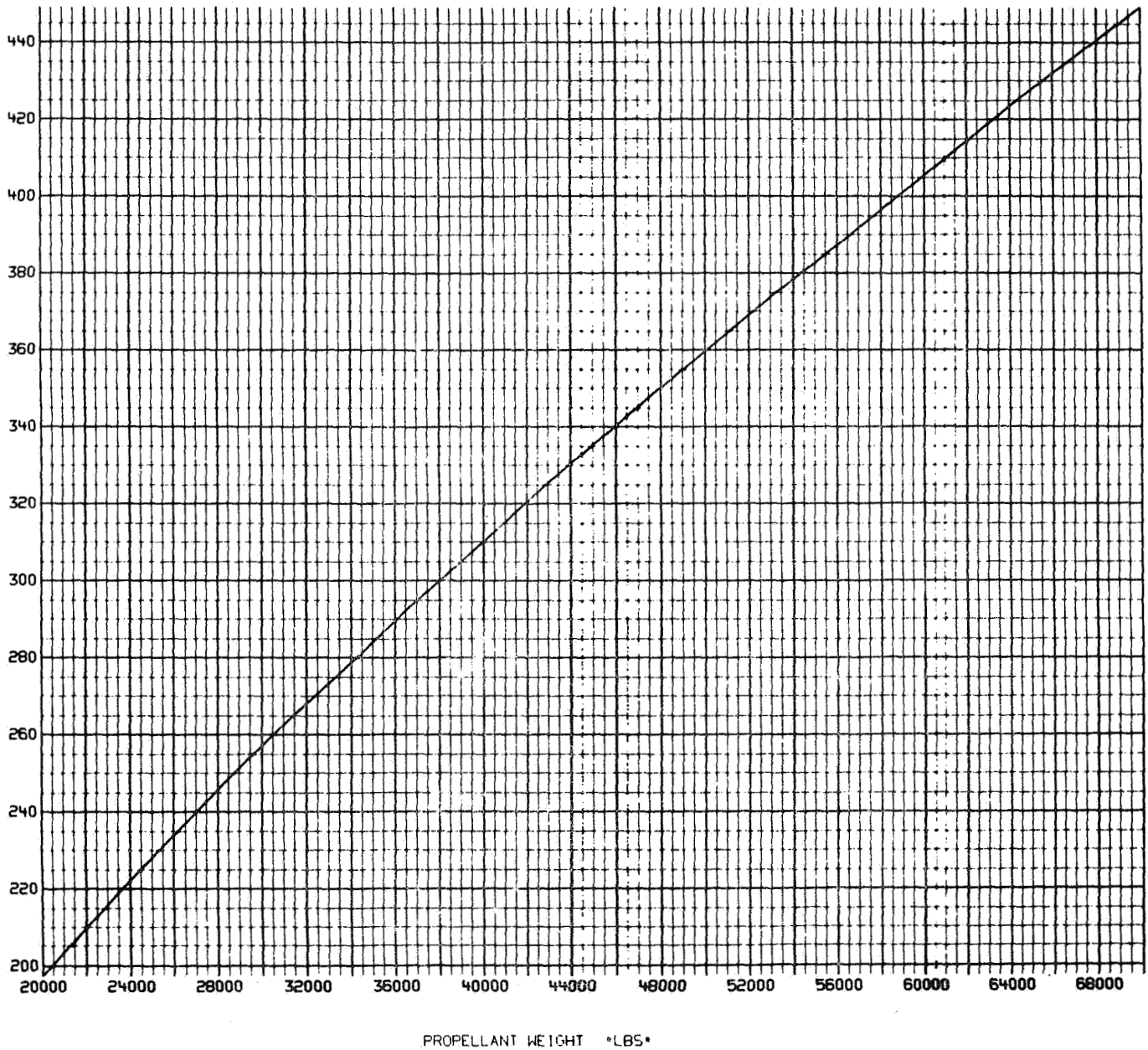


Figure 2-13

FUEL TANK

REUSEABLE MODE

LOX HYDROGEN PROPELLANT

10000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

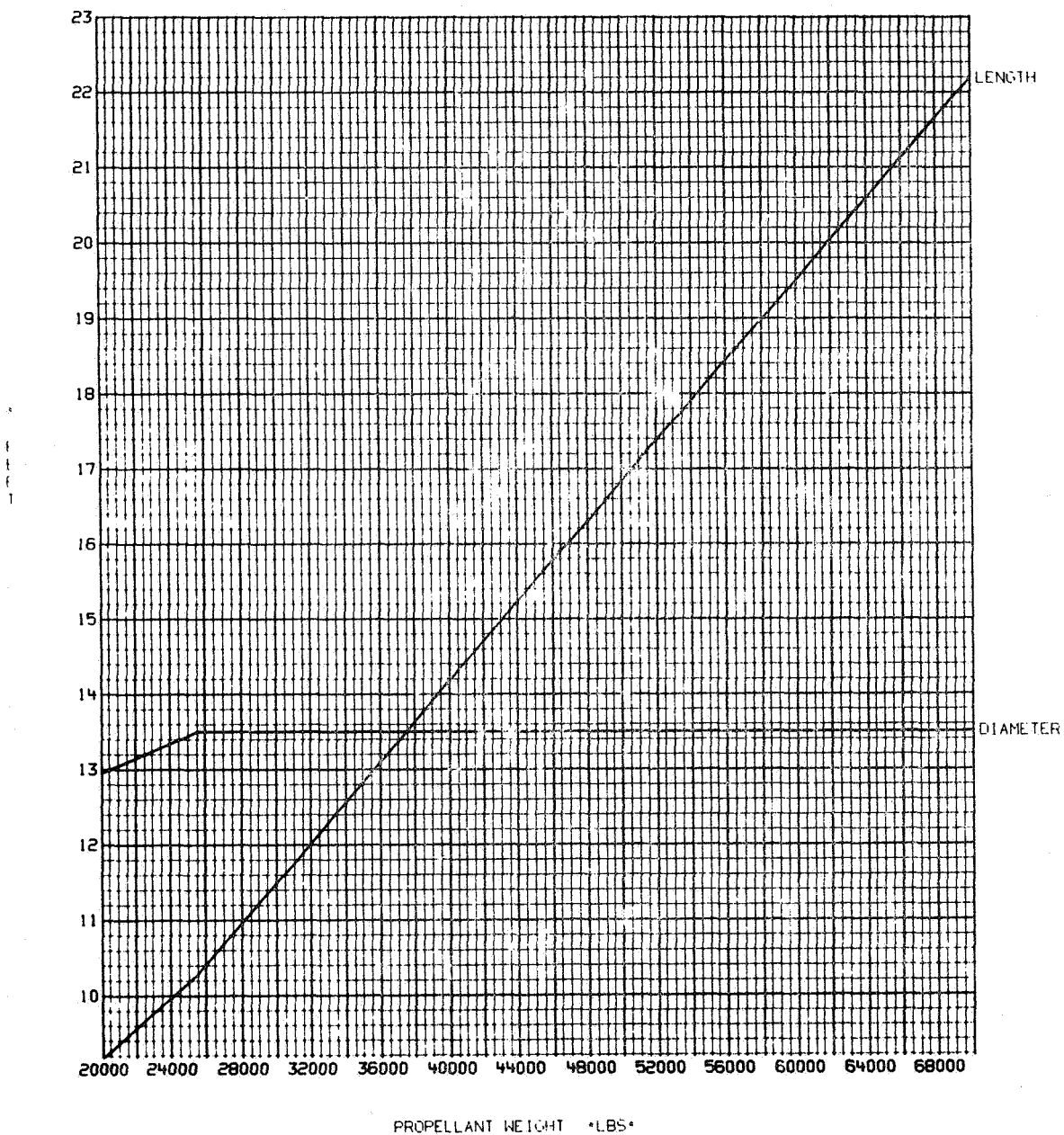


Figure 2-14

FUEL TANK

20000 LBS. THRUST

REUSABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

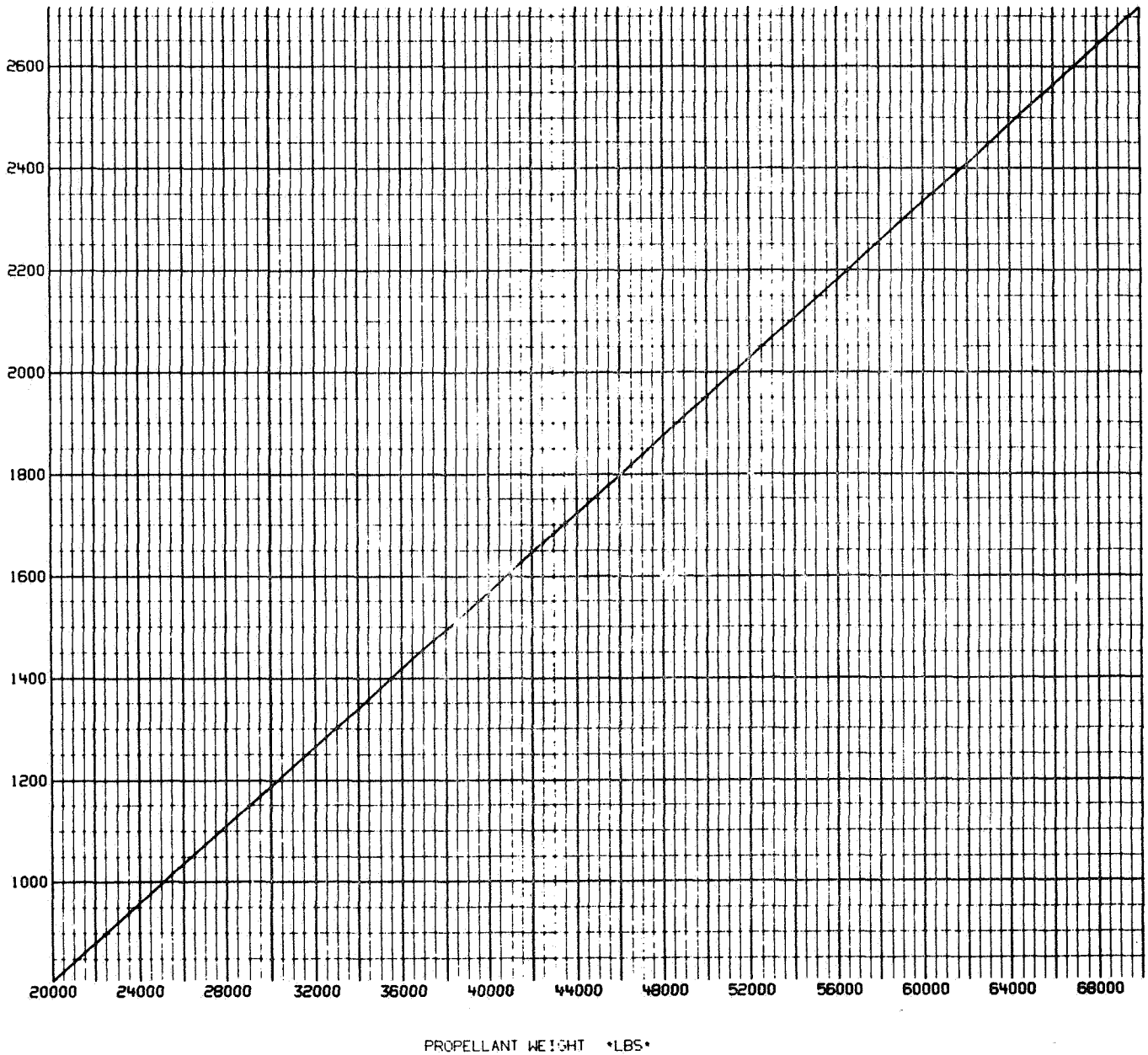


Figure 2-15

REEL TANK

PROPELLANT THROTT

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOW HYDROGEN PROPELLANT

450.0 SEC. SPECIFIC IMPULSE

A
R
E
A

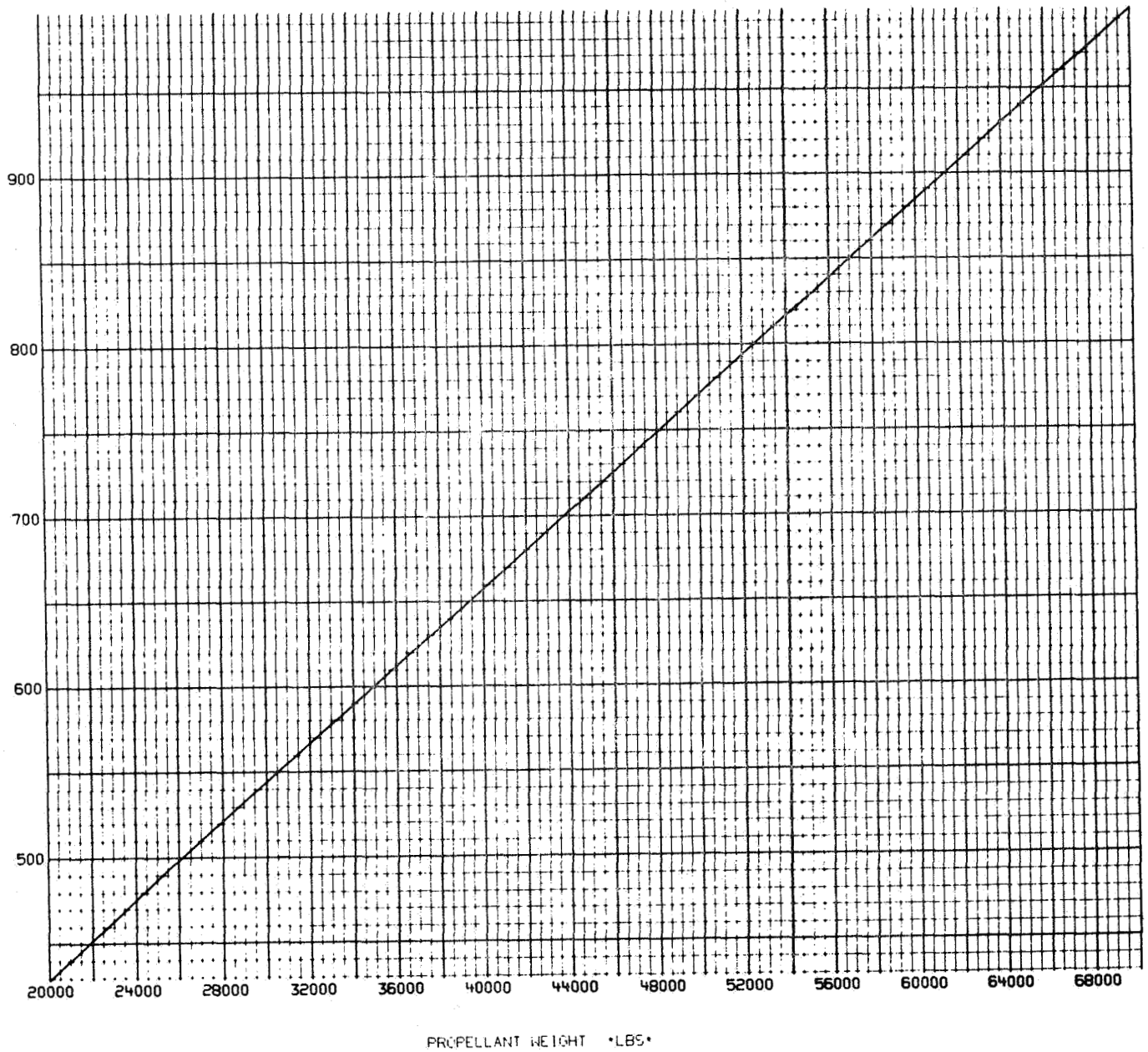


Figure 2-16

AREA OF CYLINDER * ONE

20000 LBS. THRUST

REUSEABLE NODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

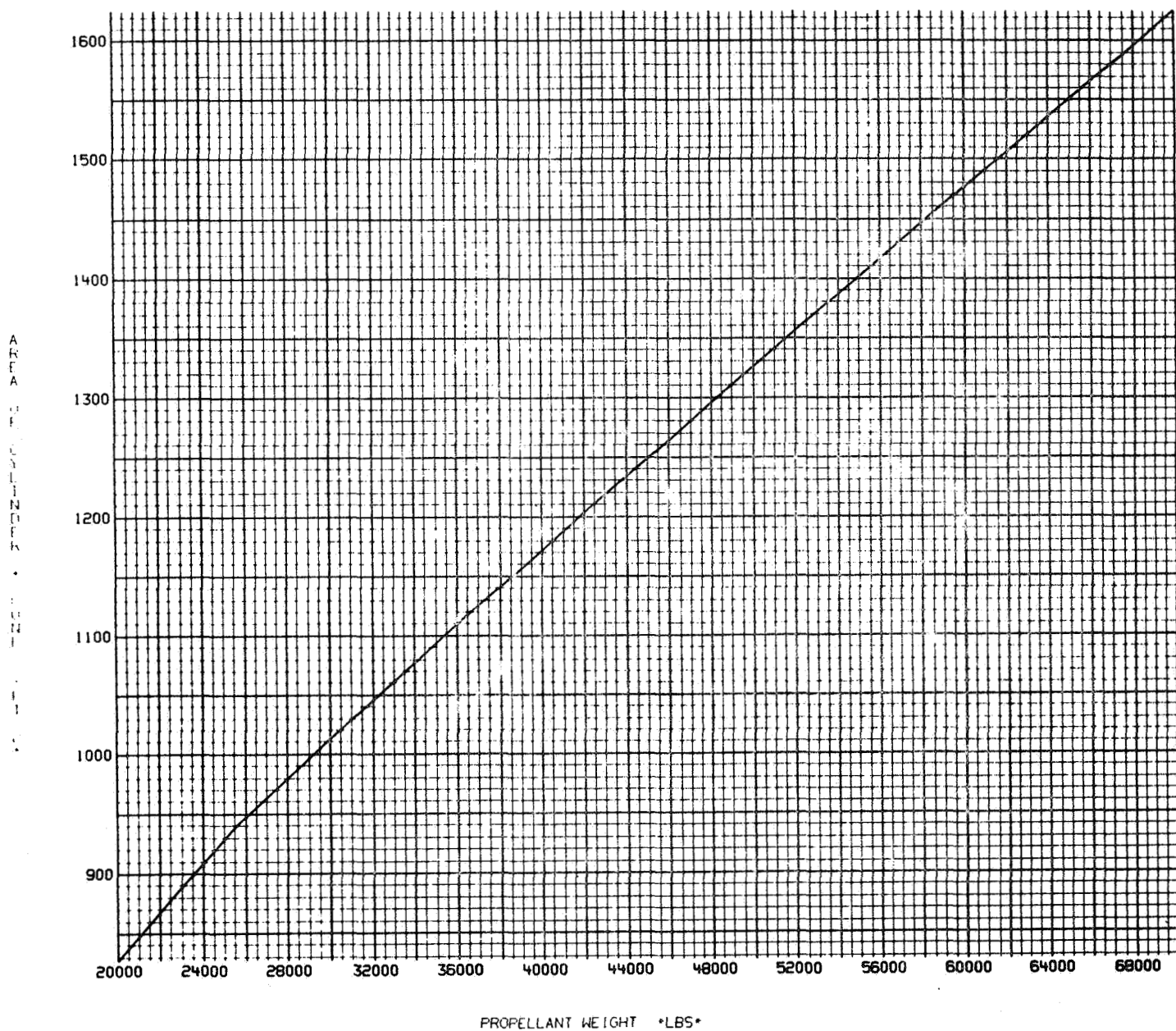


Figure 2-17

STAGE LENGTH

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

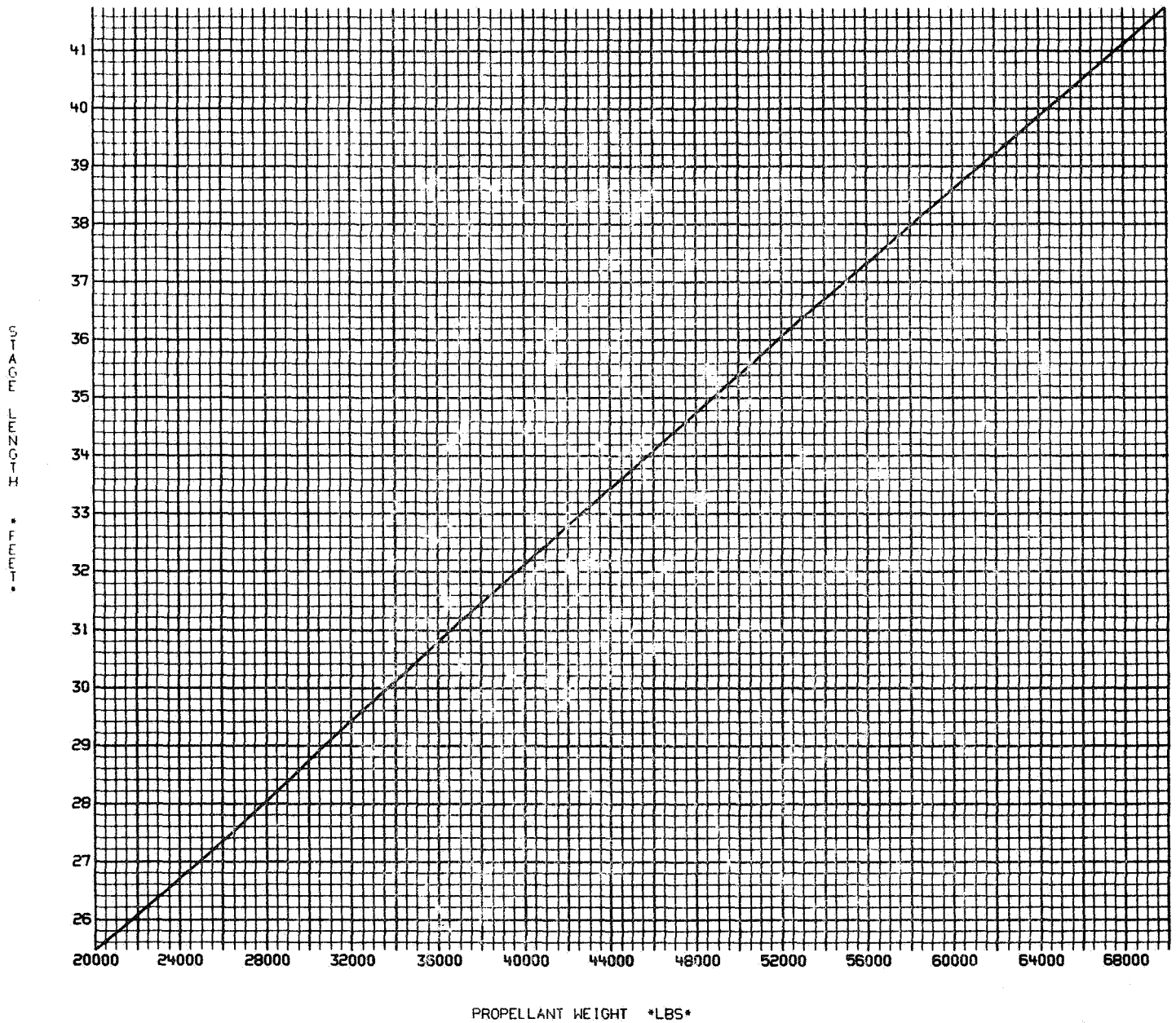


Figure 2-18

STRUCTURE

EXPENDABLE MODE

LOX HYDROGEN PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

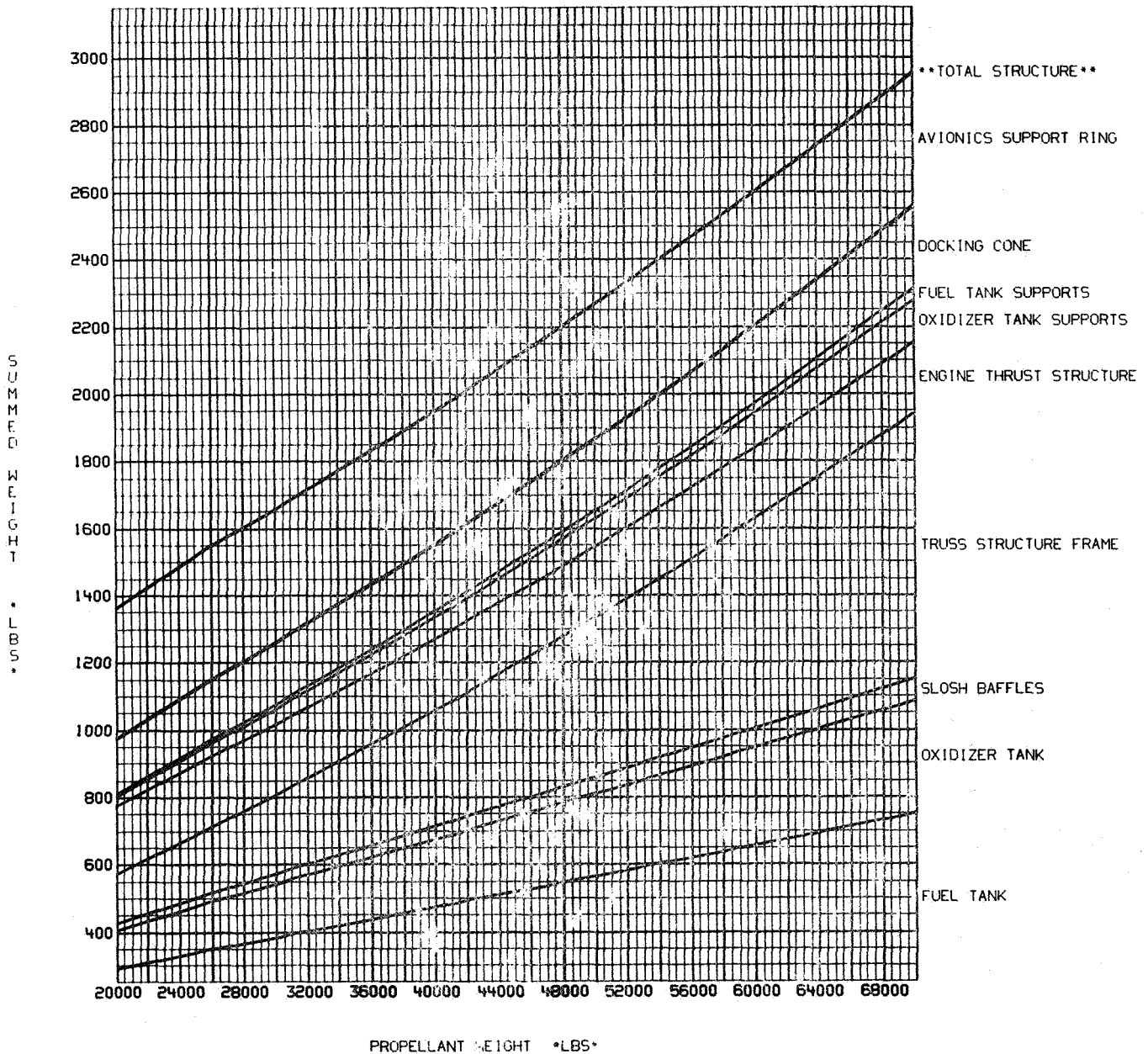


Figure 2-19

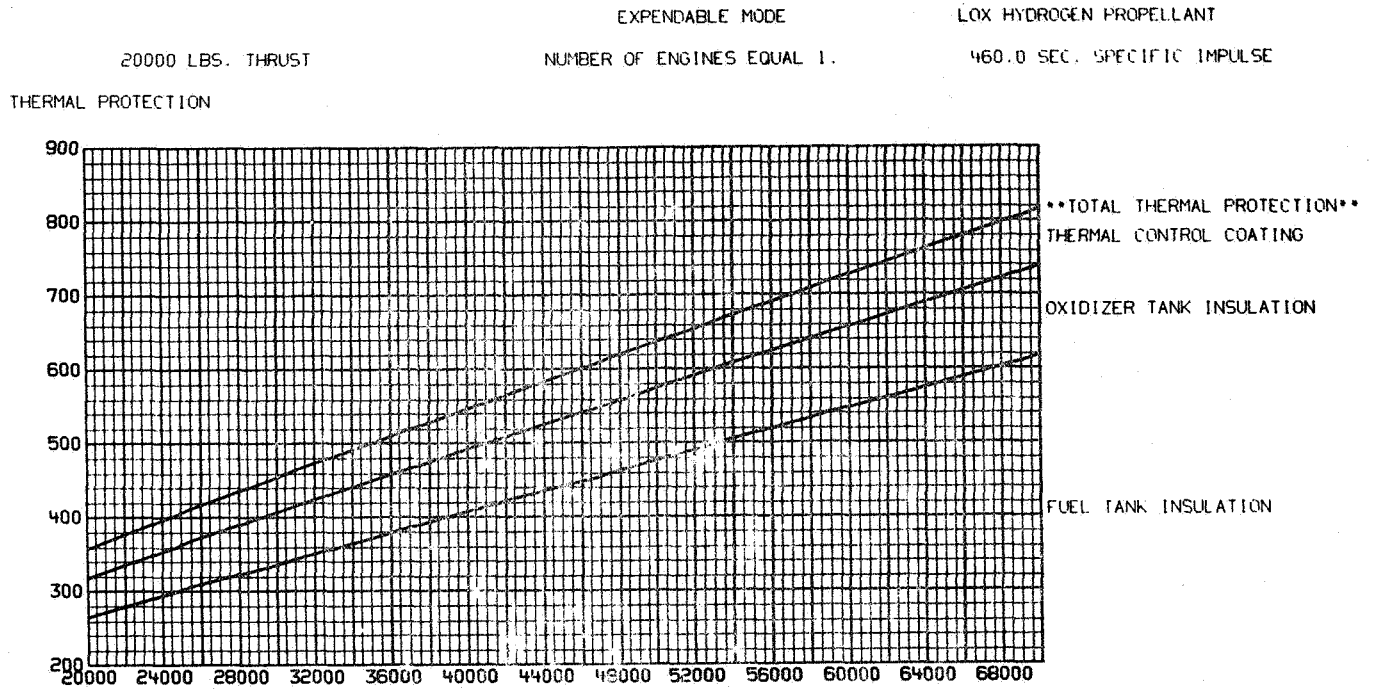


Figure 2-20

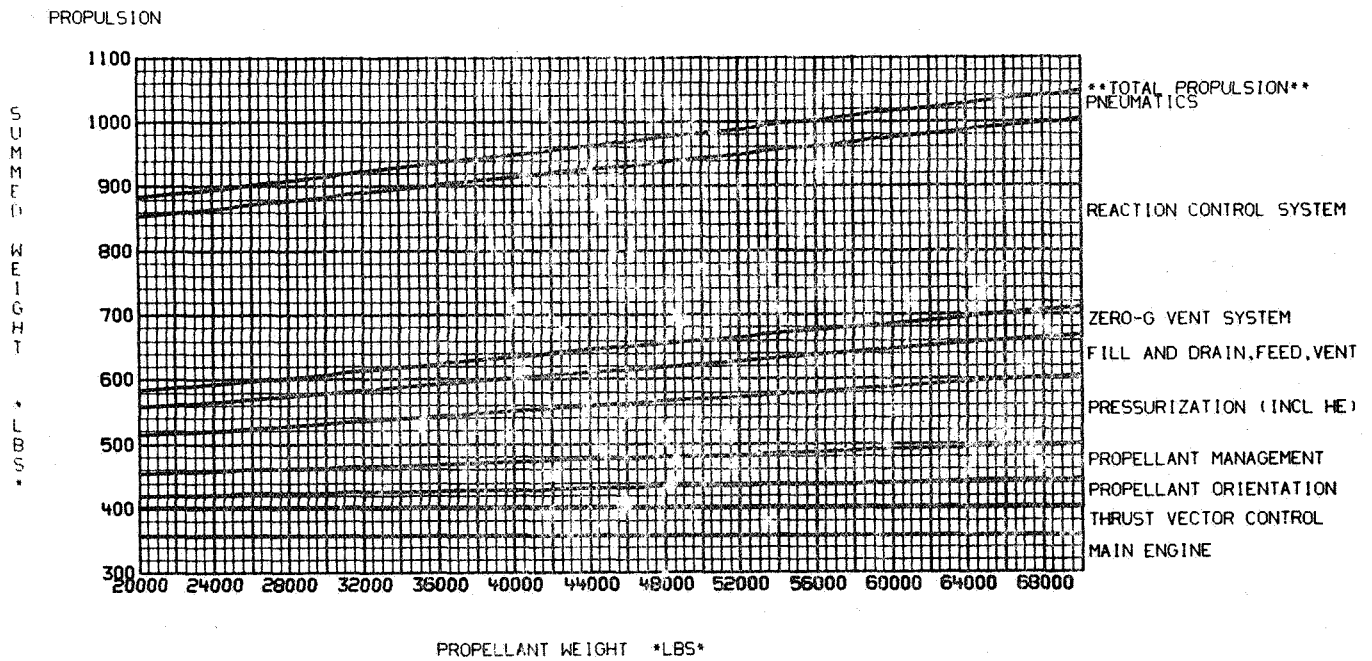


Figure 2-21

AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

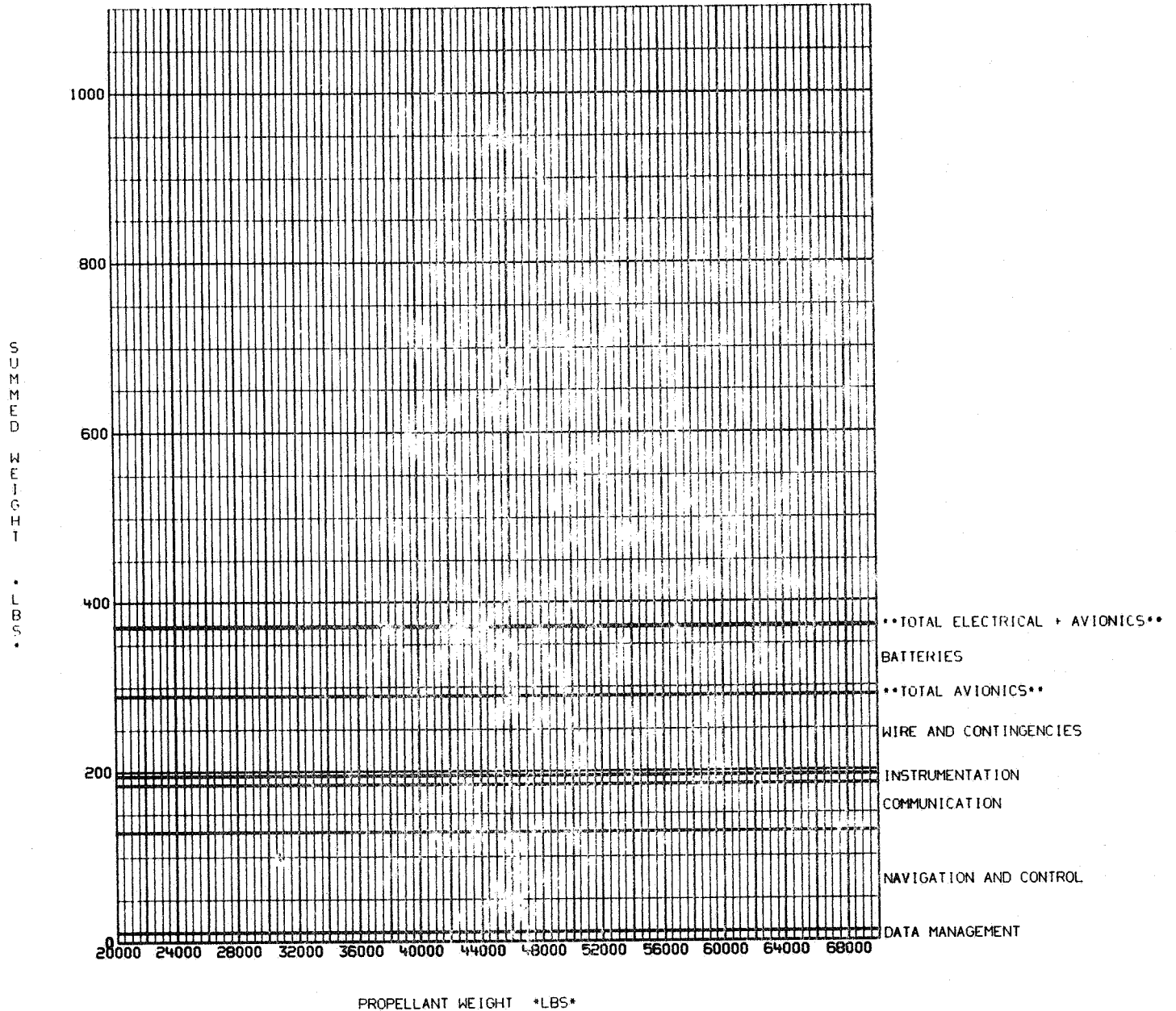


Figure 2-22

EXPENDABLE MODE
 20000 LBS. THRUST
 NUMBER OF ENGINES EQUAL 1.
 LOX HYDROGEN PROPELLANT
 460.0 SEC. SPECIFIC IMPULSE
 NON - USEABLE FLUIDS

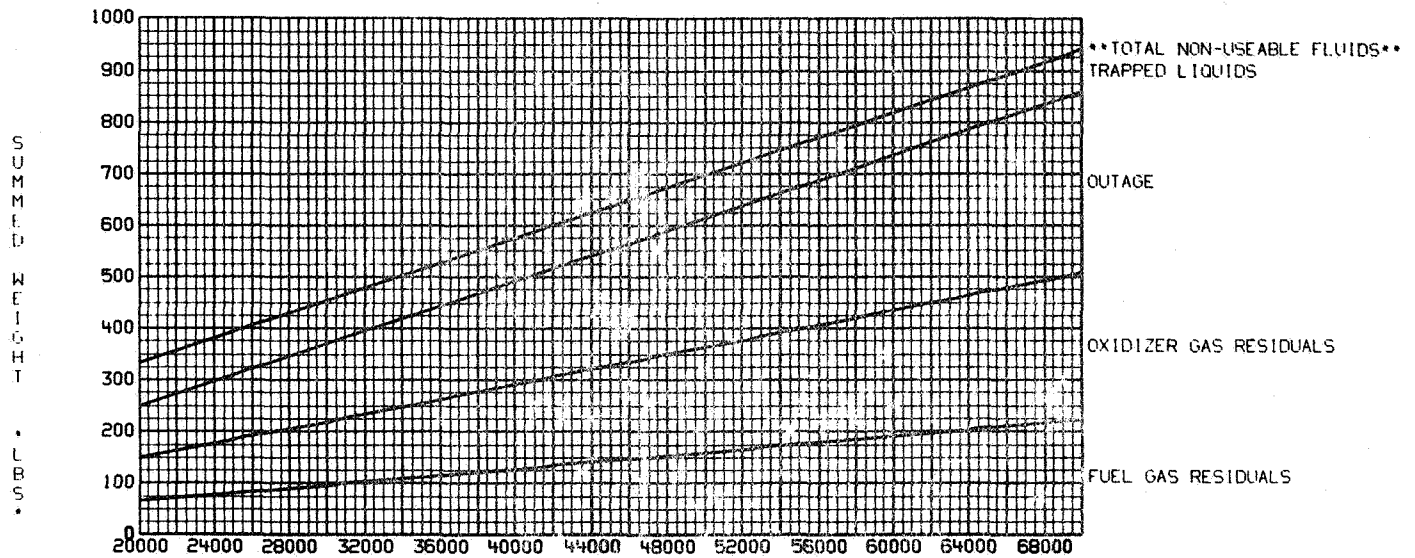


Figure 2-23

NON - IMPULSE CONSUMABLES

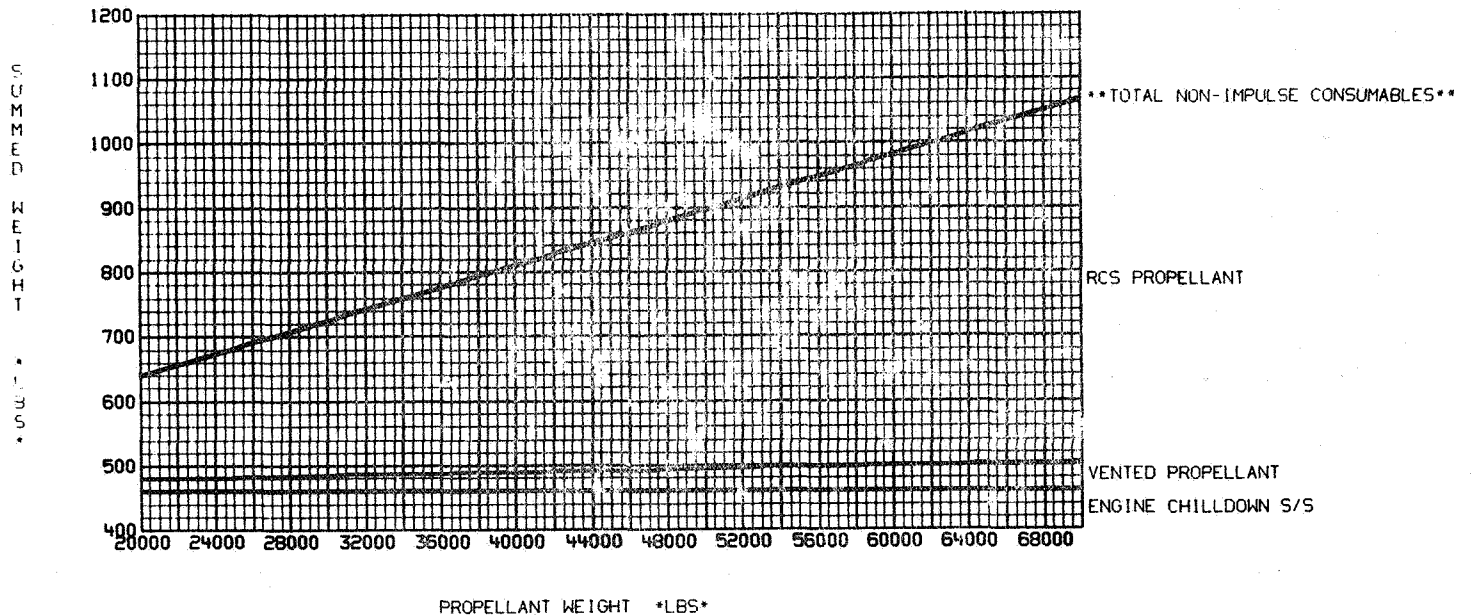


Figure 2-24

ADVANCED TUG SYSTEM WEIGHTS

EXPENDABLE MODE

LOX HYDROGEN PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

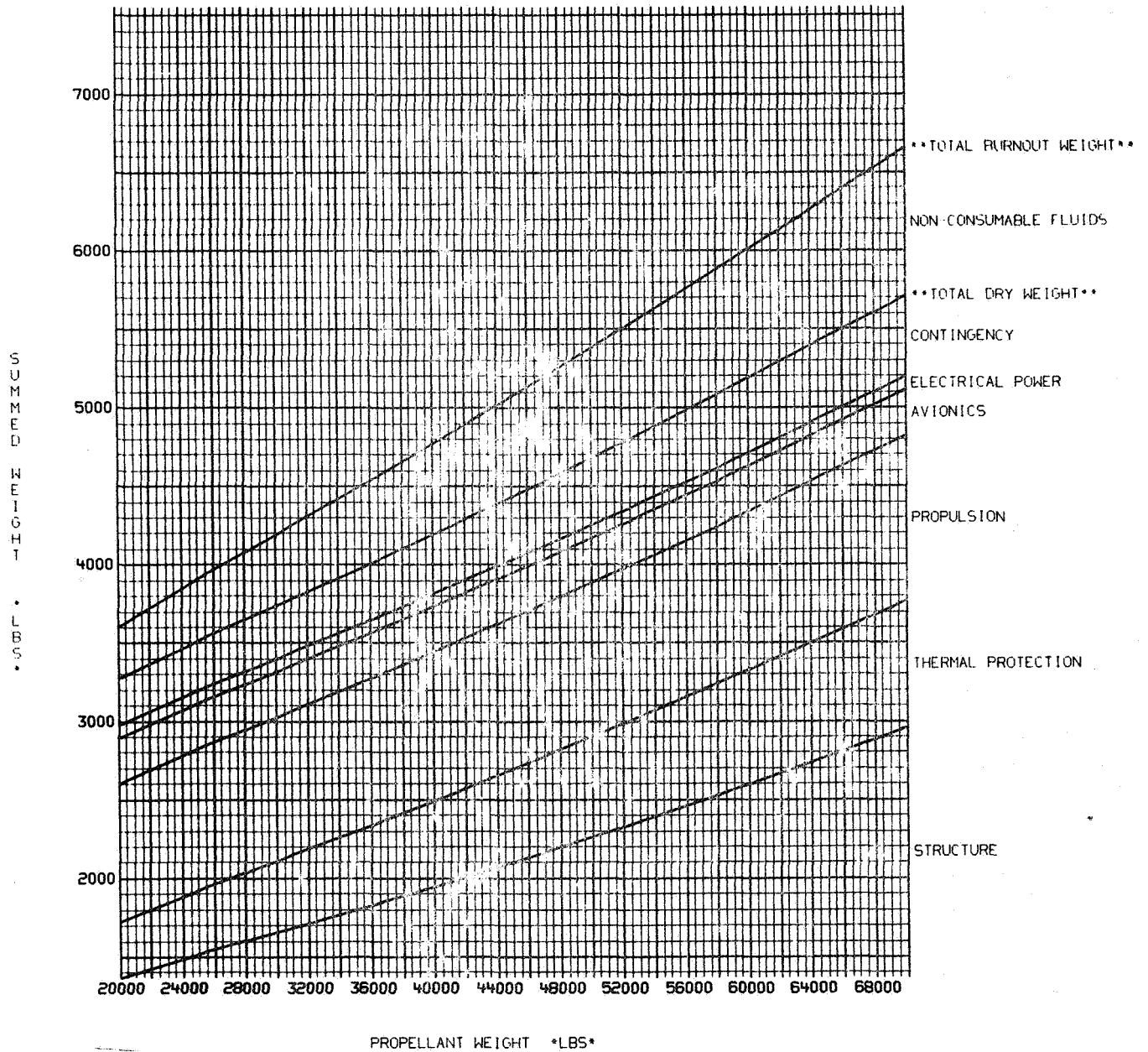


Figure 2-25

BURNOUT AND TOTAL GROSS STAGE WEIGHT

EXPENDABLE MODE

LOX HYDROGEN PROPELLANT

70000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

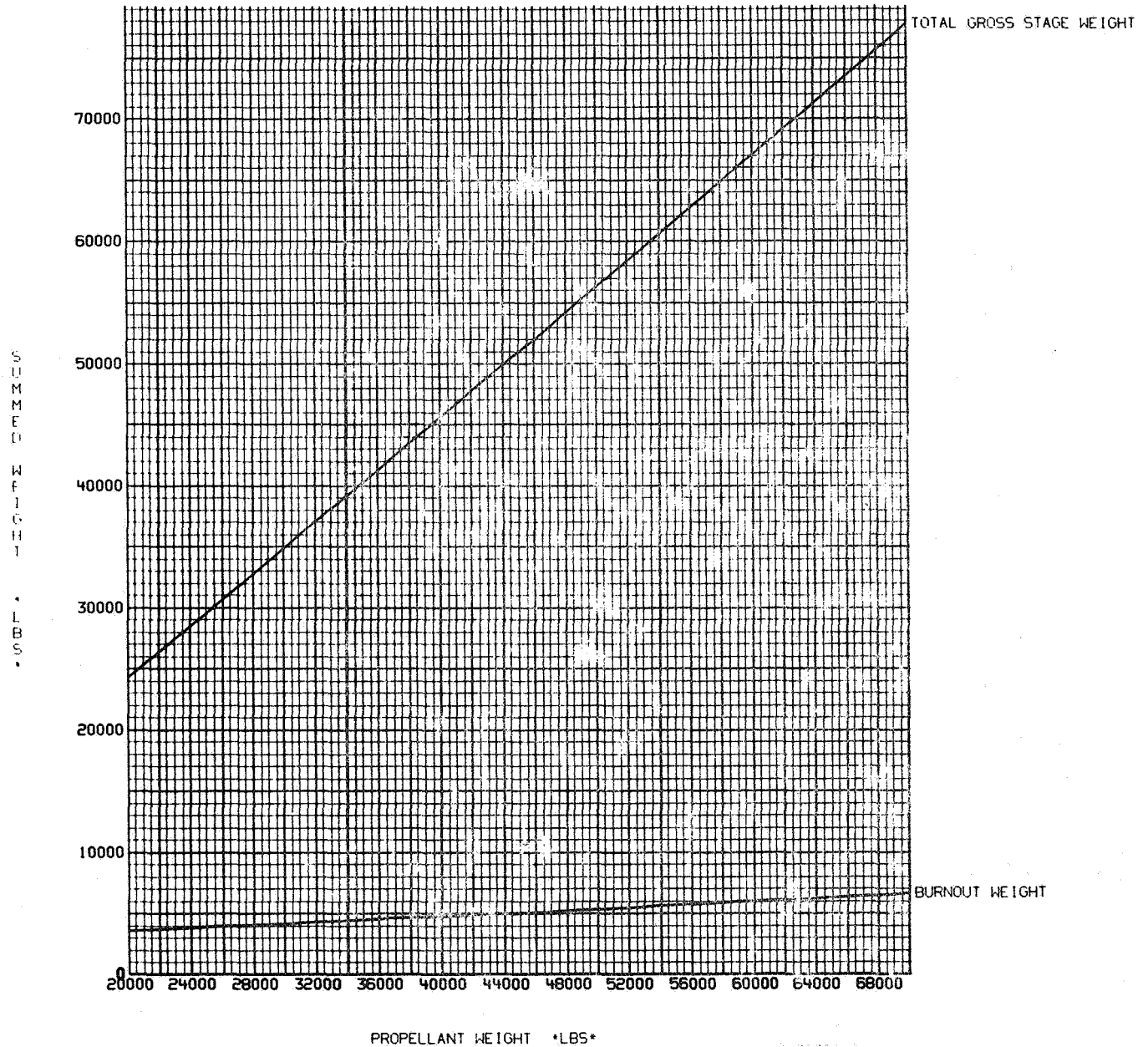


Figure 2-26

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
10000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT
460.0 SEC. SPECIFIC IMPULSE

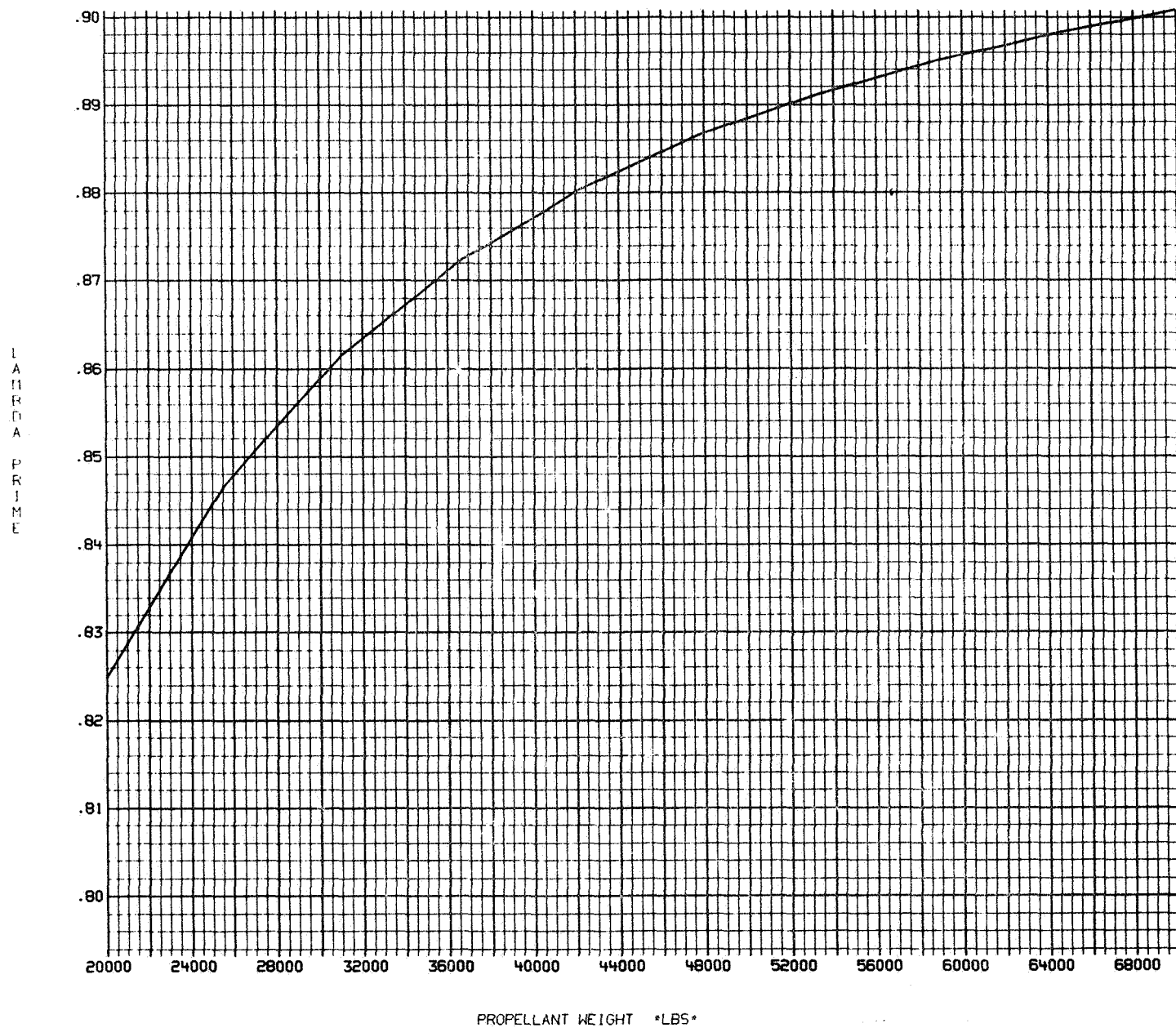


Figure 2-27

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP. EXPENDABLE MODE

LOX HYDROGEN PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

460.0 SEC. SPECIFIC IMPULSE

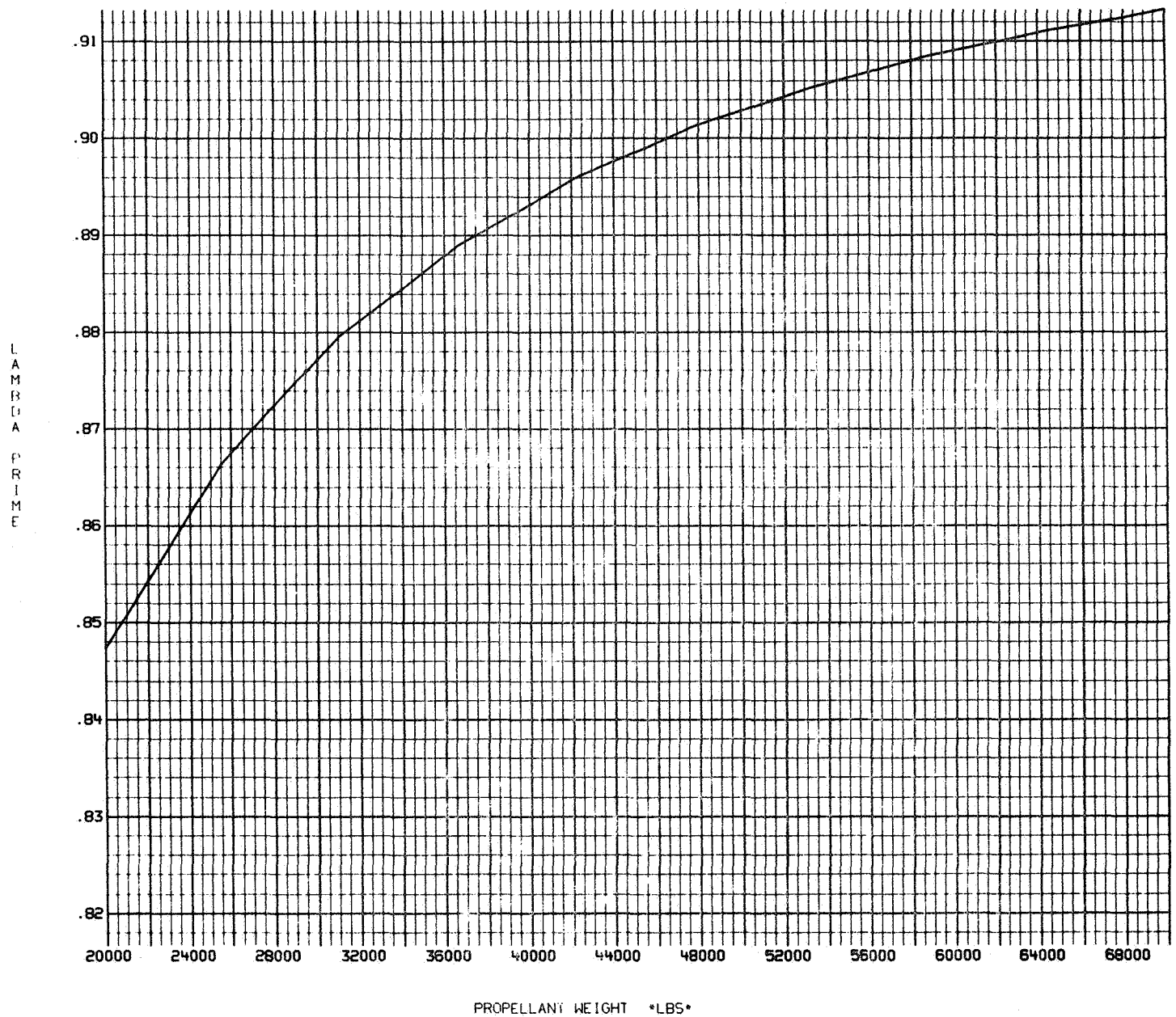


Figure 2-28

AREA OF CYLINDER + CONE

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460.0 SEC. SPECIFIC IMPULSE

AREA
OF
CYLINDER
+
CONE
*
FT.²

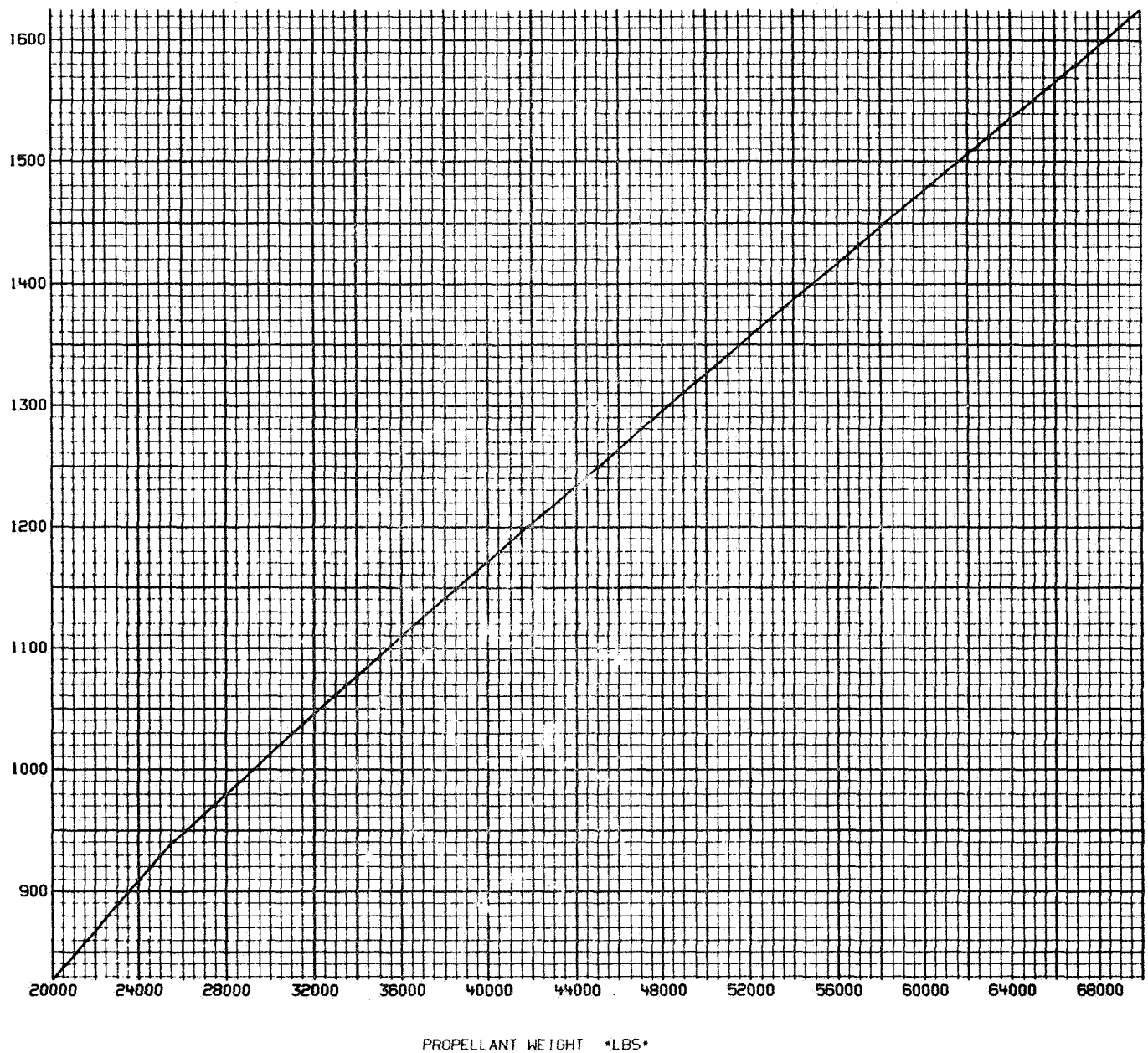


Figure 2-29

STRUCTURE

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

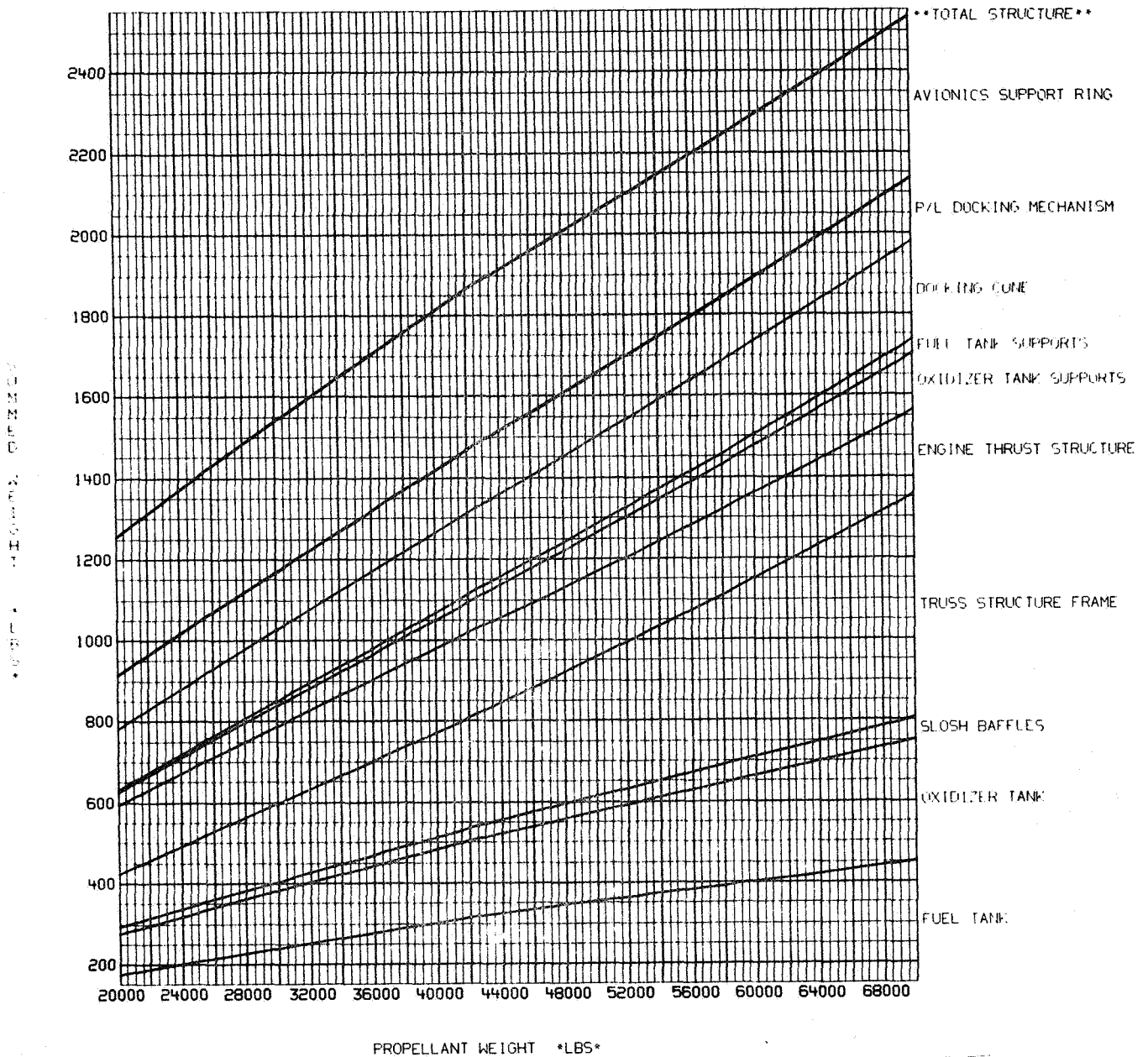


Figure 2-30

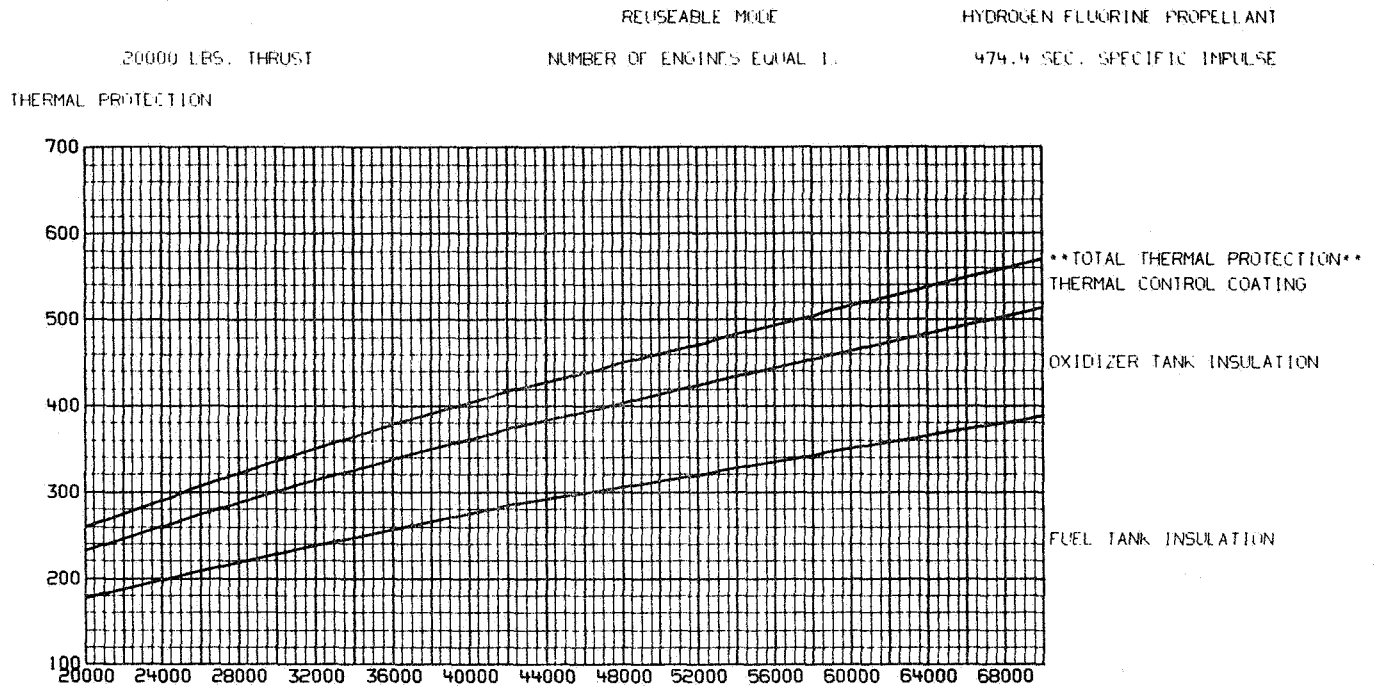


Figure 2-31

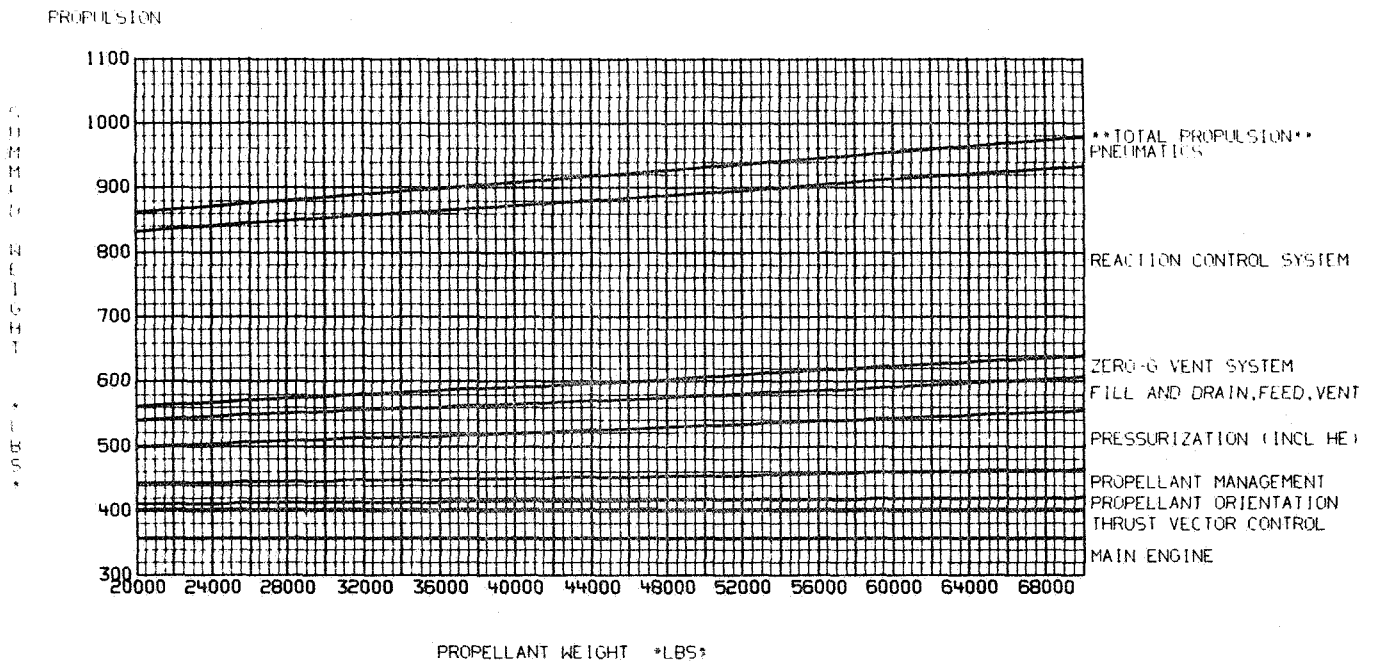


Figure 2-32

AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

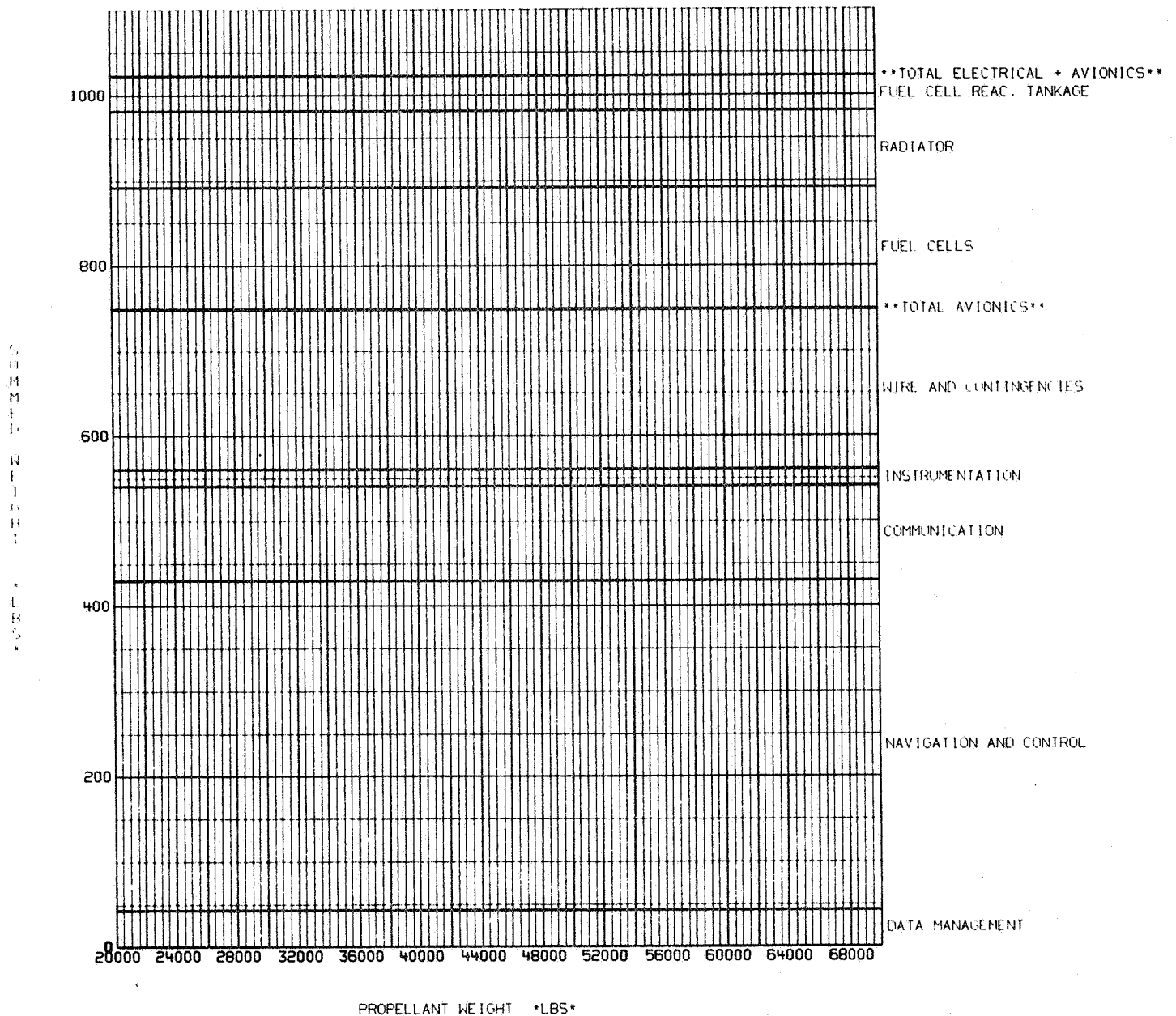


Figure 2-33

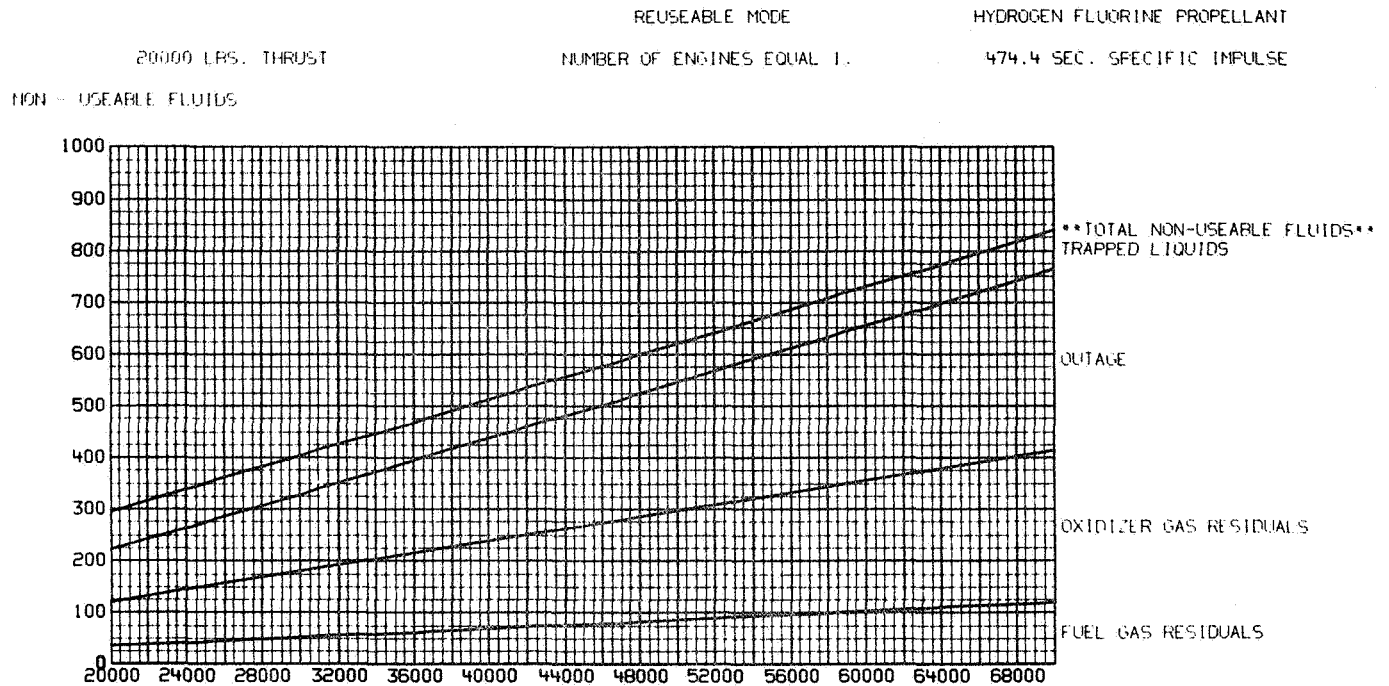


Figure 2-34

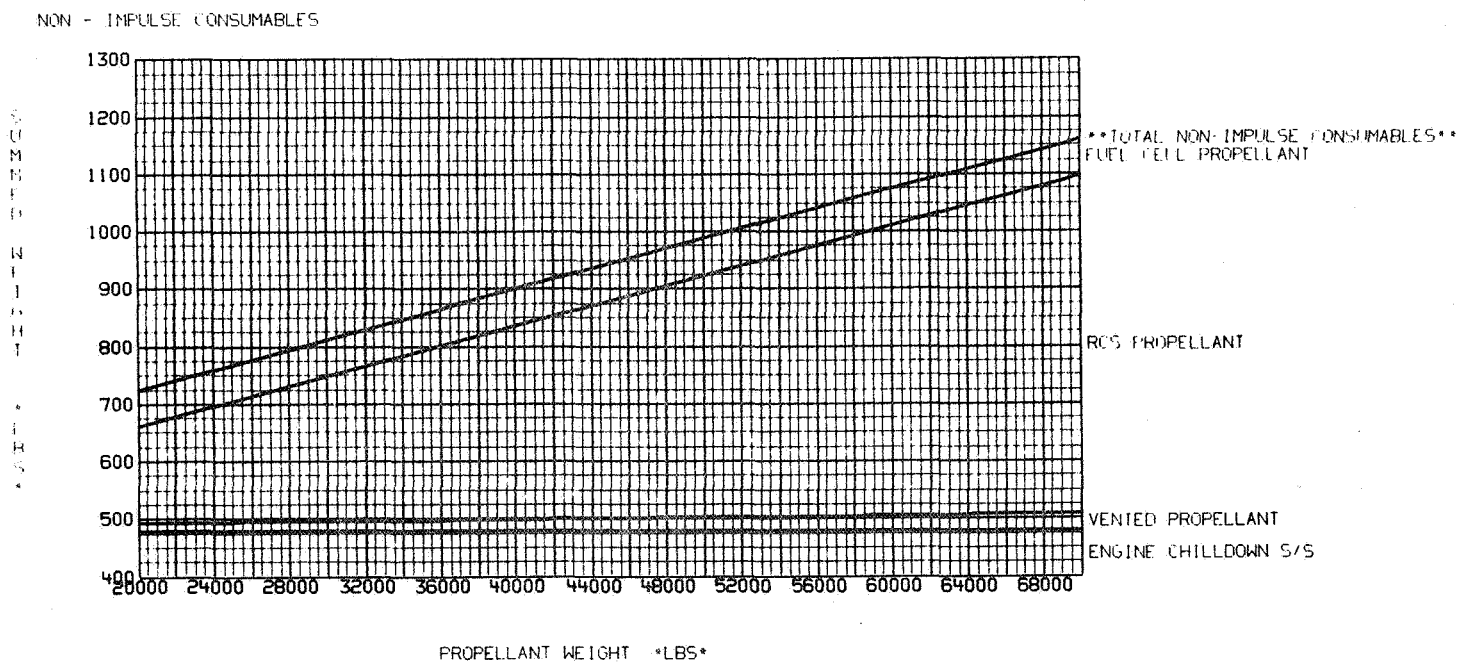


Figure 2-35

ADVANCED TUG SYSTEM HEIGHTS

10000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

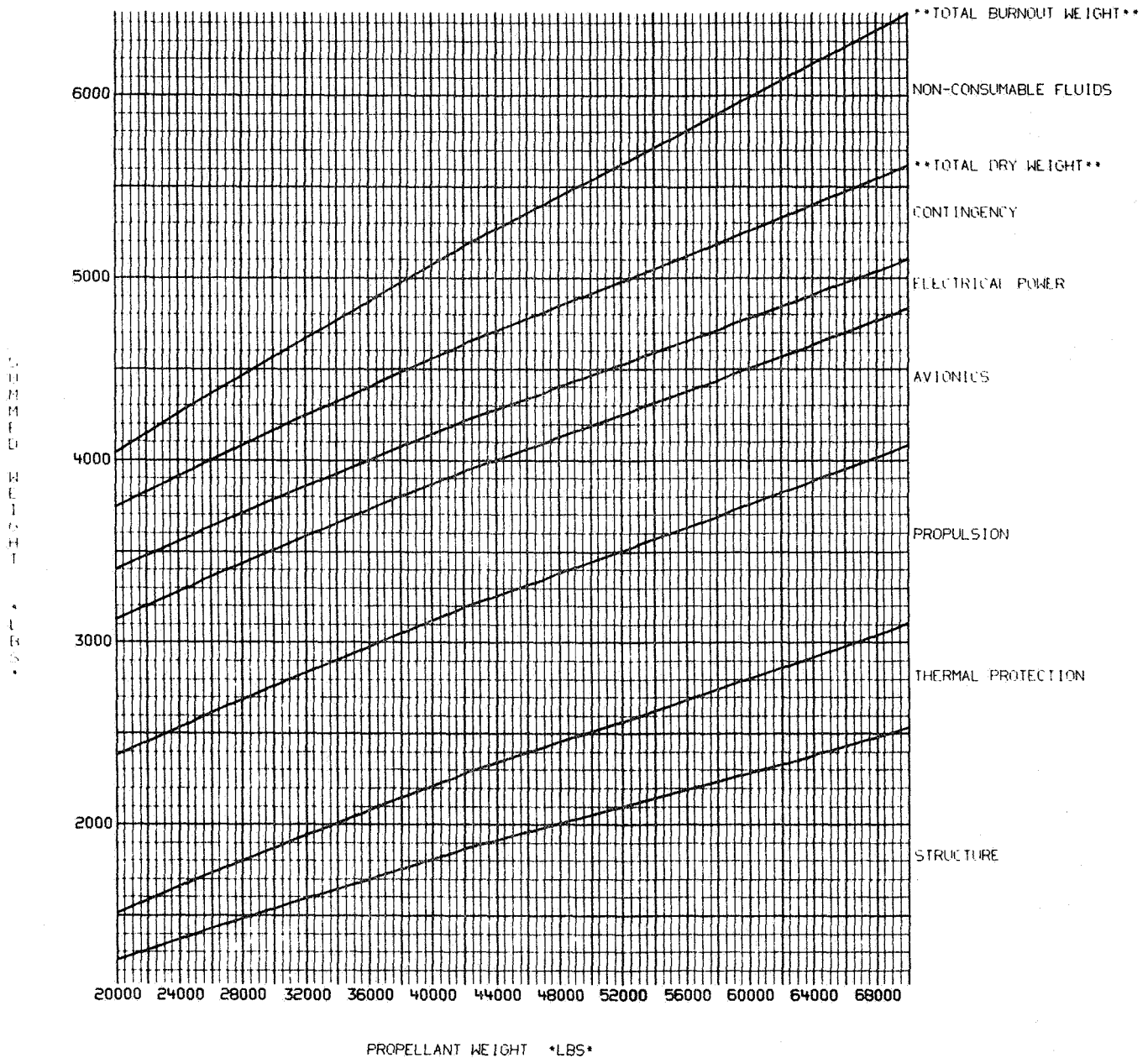


Figure 2-36

BURNOUT AND TOTAL GROSS STAGE WEIGHT

REUSEABLE MODE

HYDROGEN FLUORINE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

474.4 SEC. SPECIFIC IMPULSE

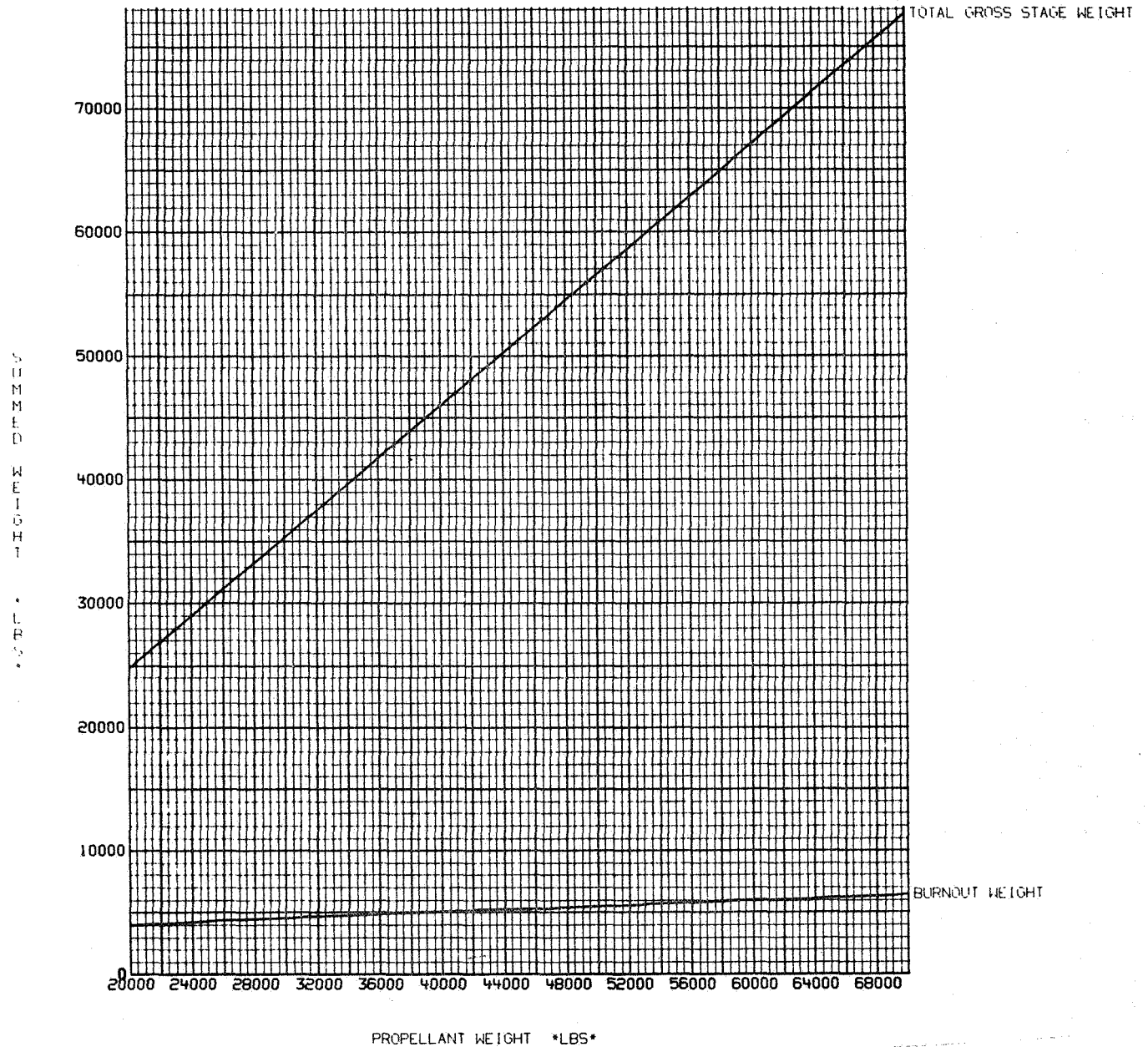


Figure 2-37

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT
10000 LBS. THRUST

REUSEABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIED IMPULSE

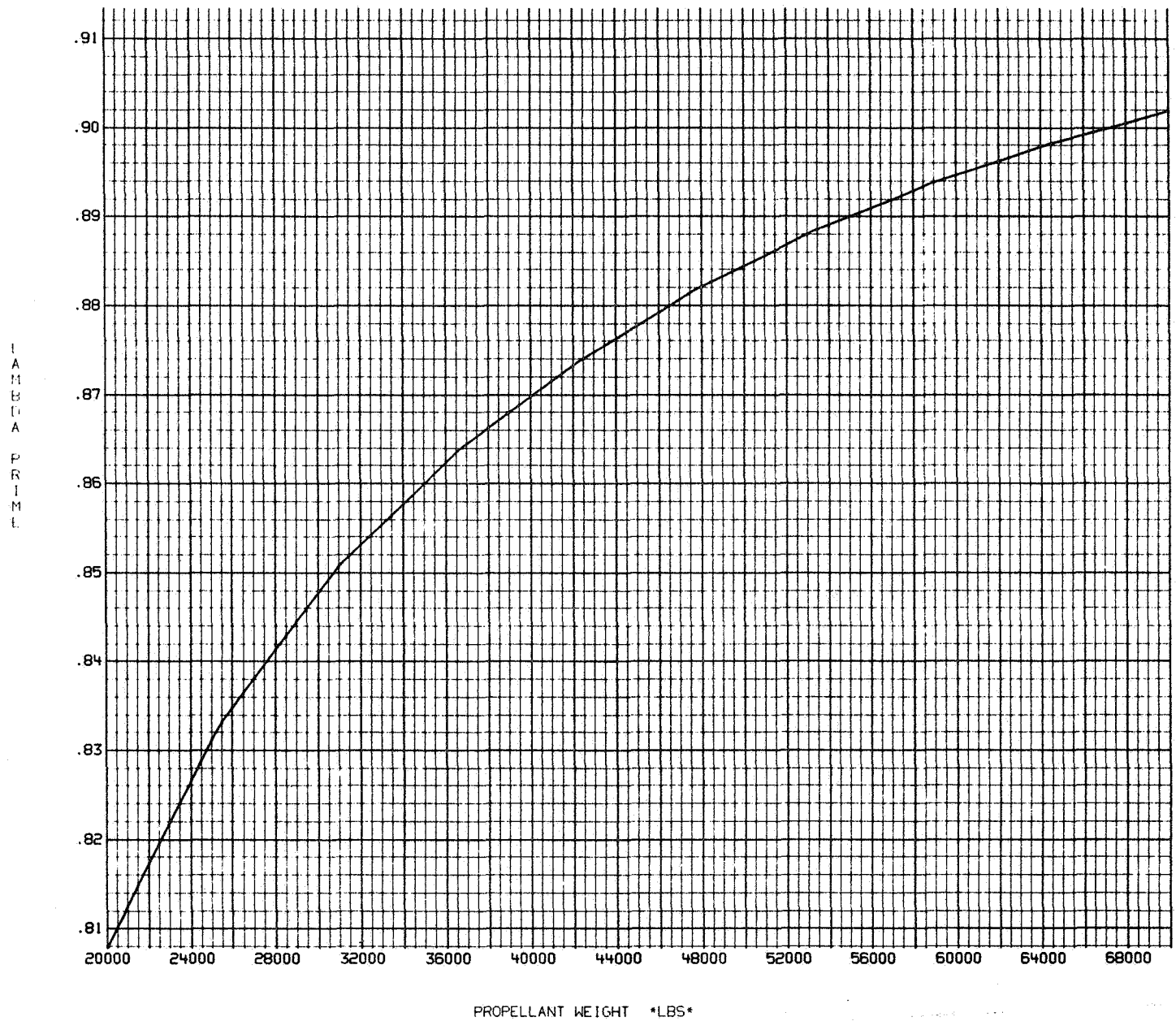


Figure 2-38

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP. REUSEABLE MODE HYDROGEN FLUORINE PROPELLANT
20000 LBS. THRUST NUMBER OF ENGINES EQUAL 1. 474.4 SEC. SPECIFIC IMPULSE

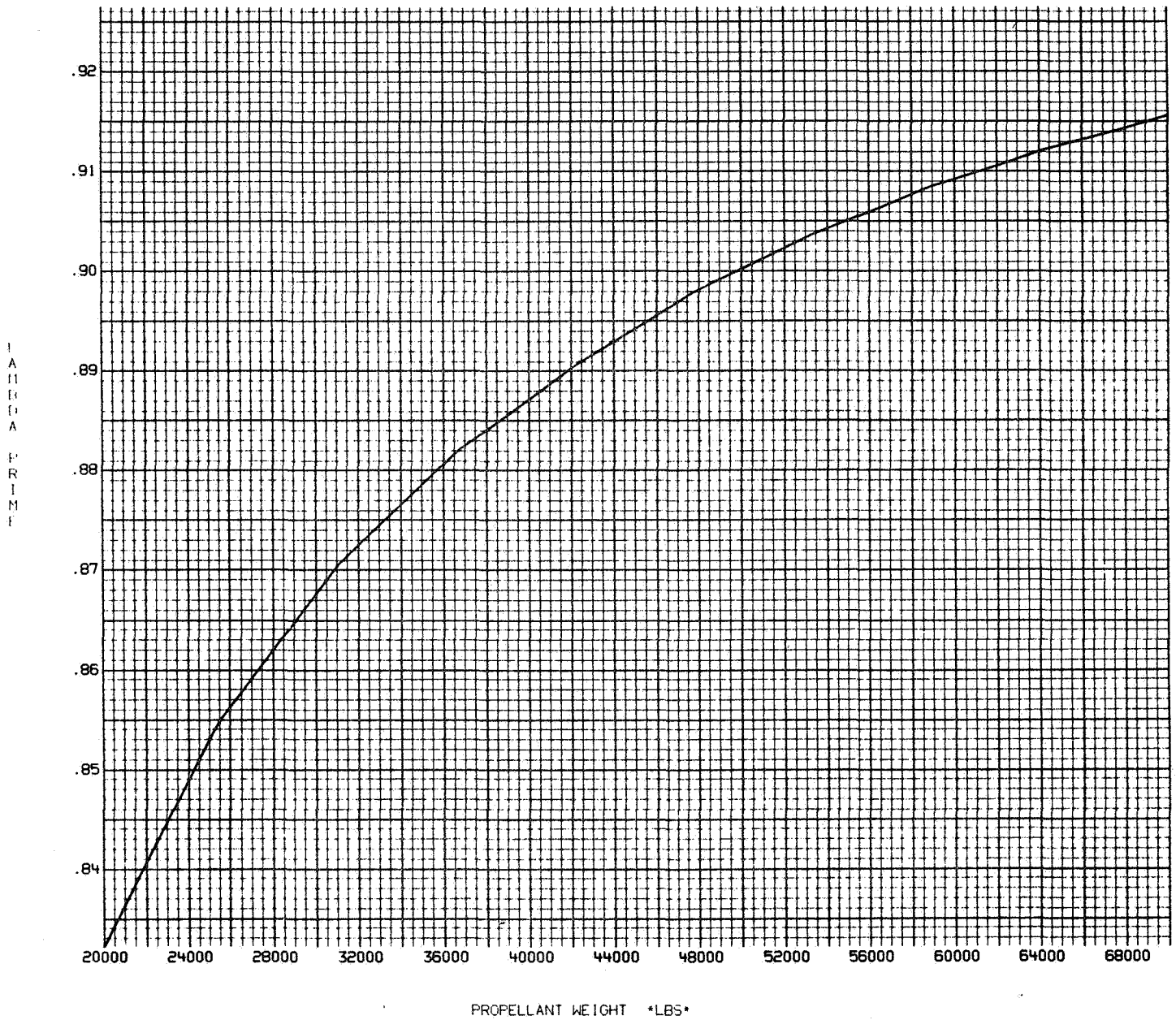


Figure 2-39

Oxidizer Tank

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

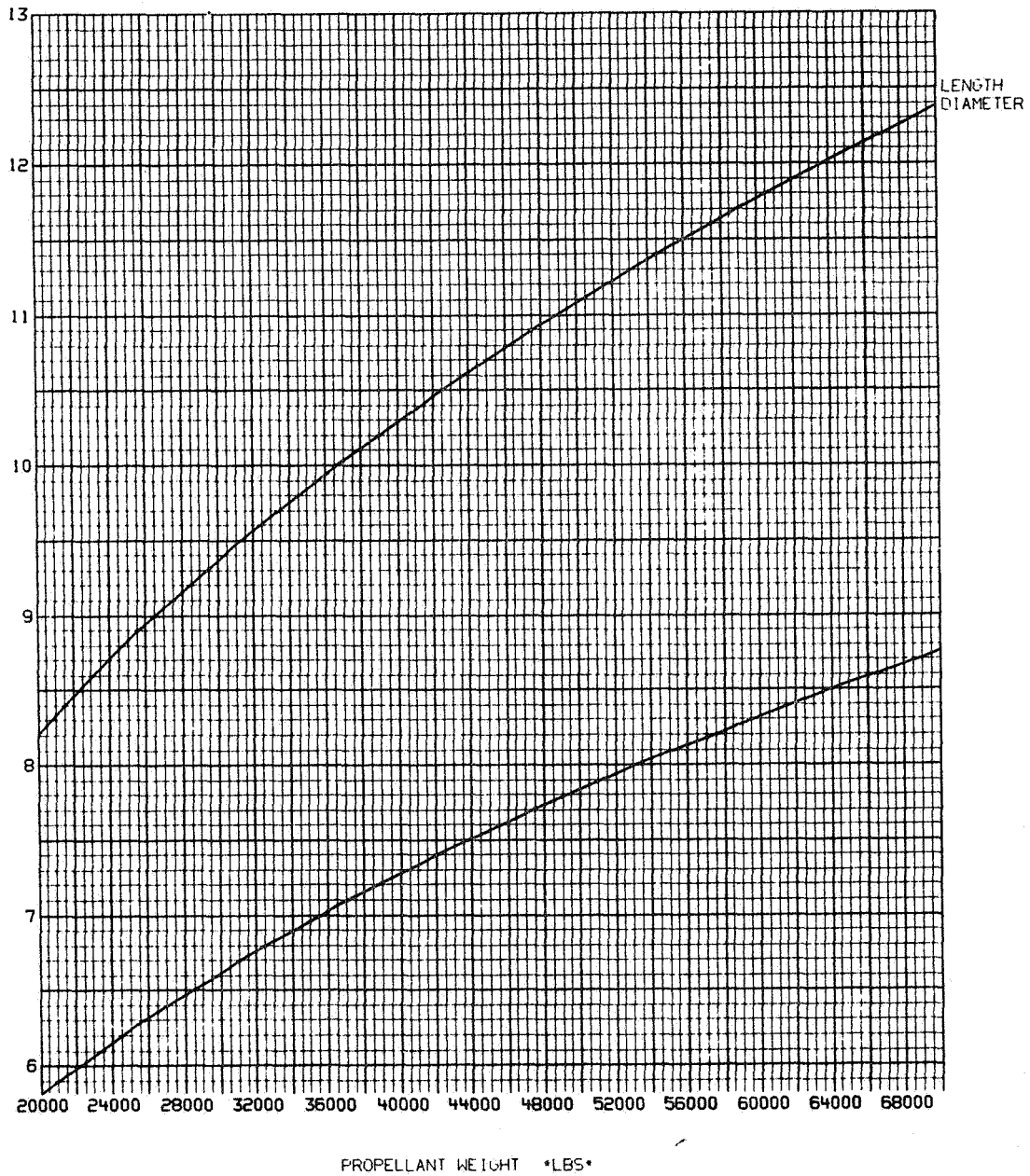


Figure 2-40

OXIDIZER TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

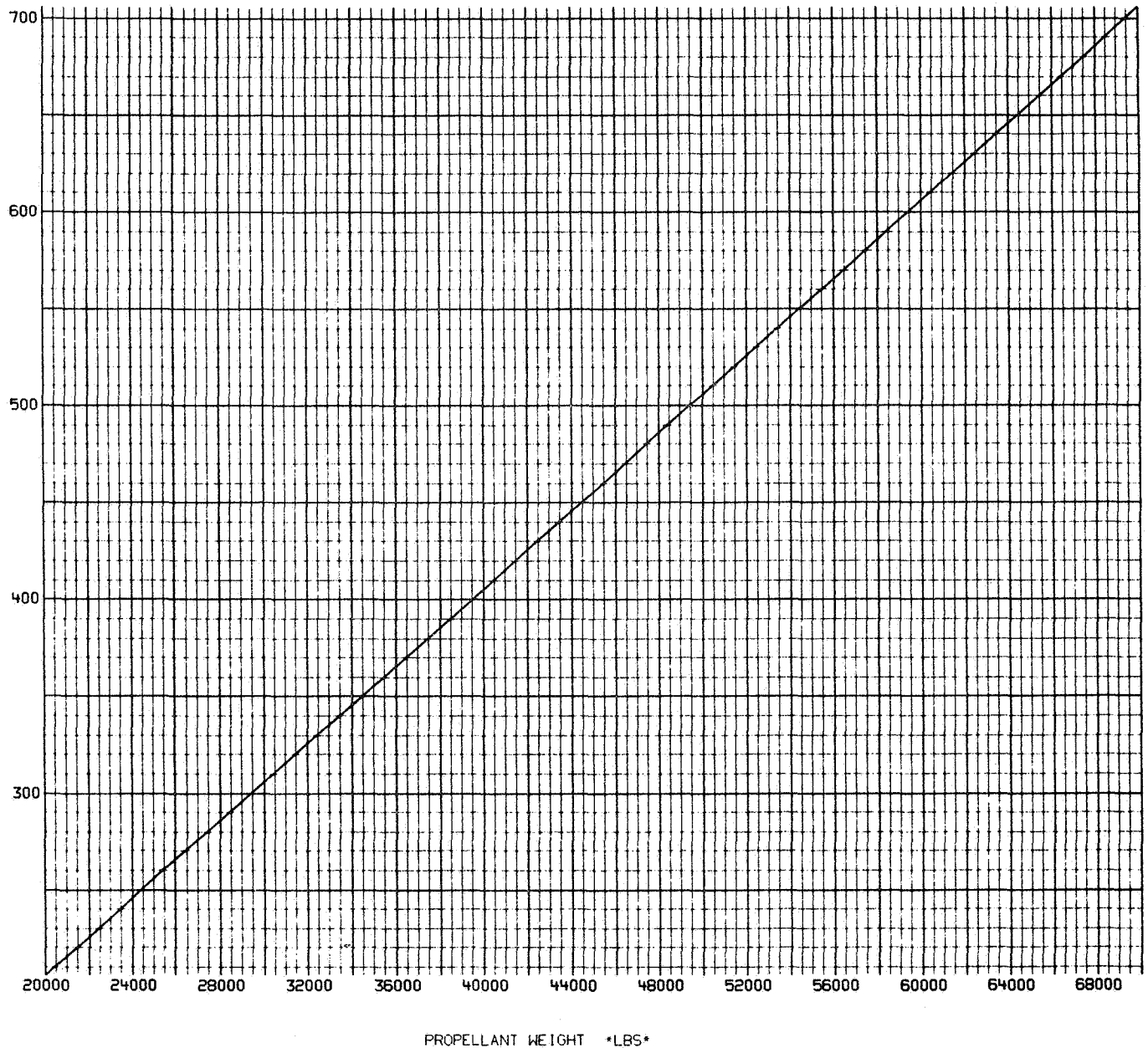


Figure 2-41

OXIDIZER TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

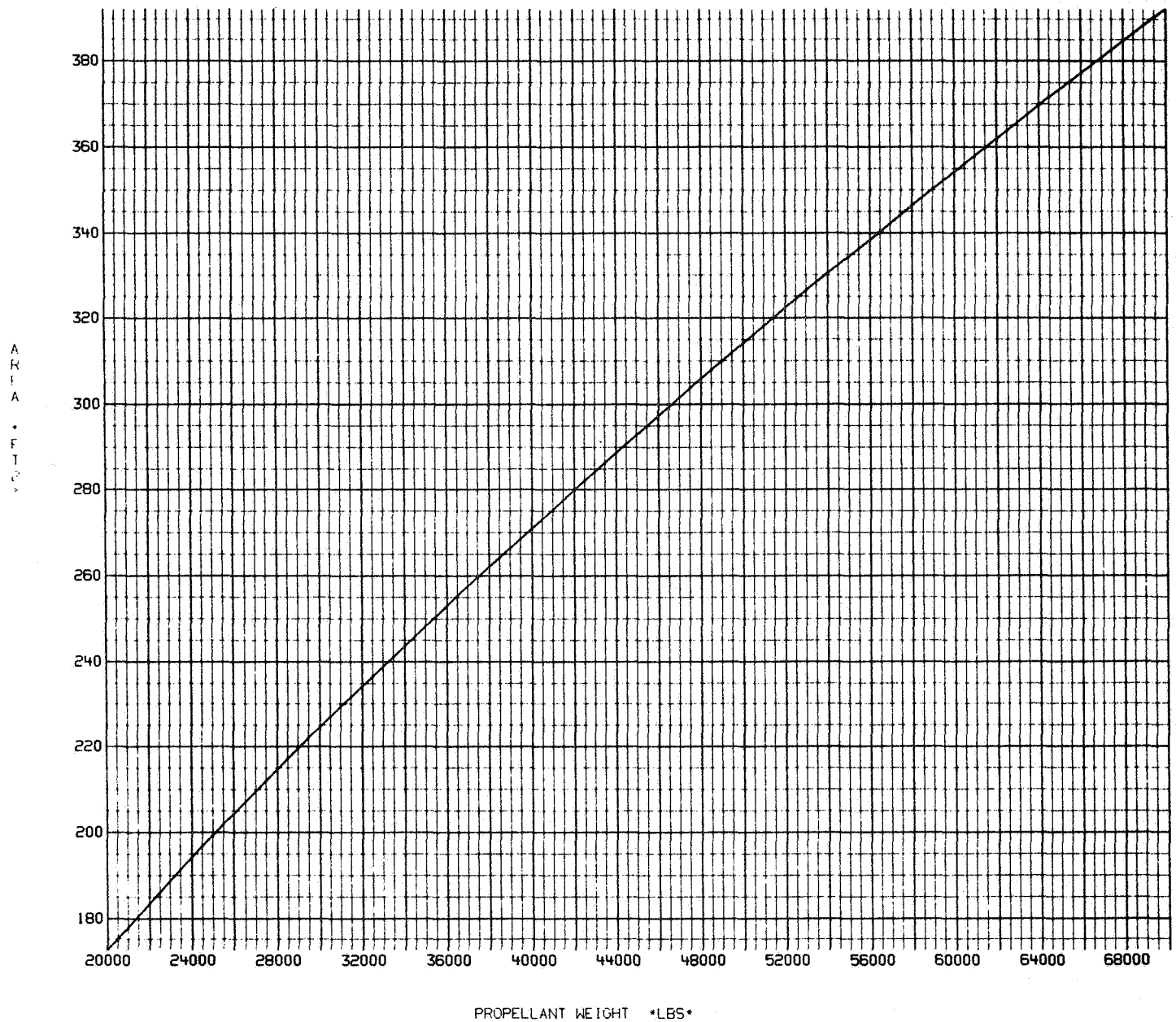


Figure 2-42

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.9 SEC. SPECIFIC IMPULSE

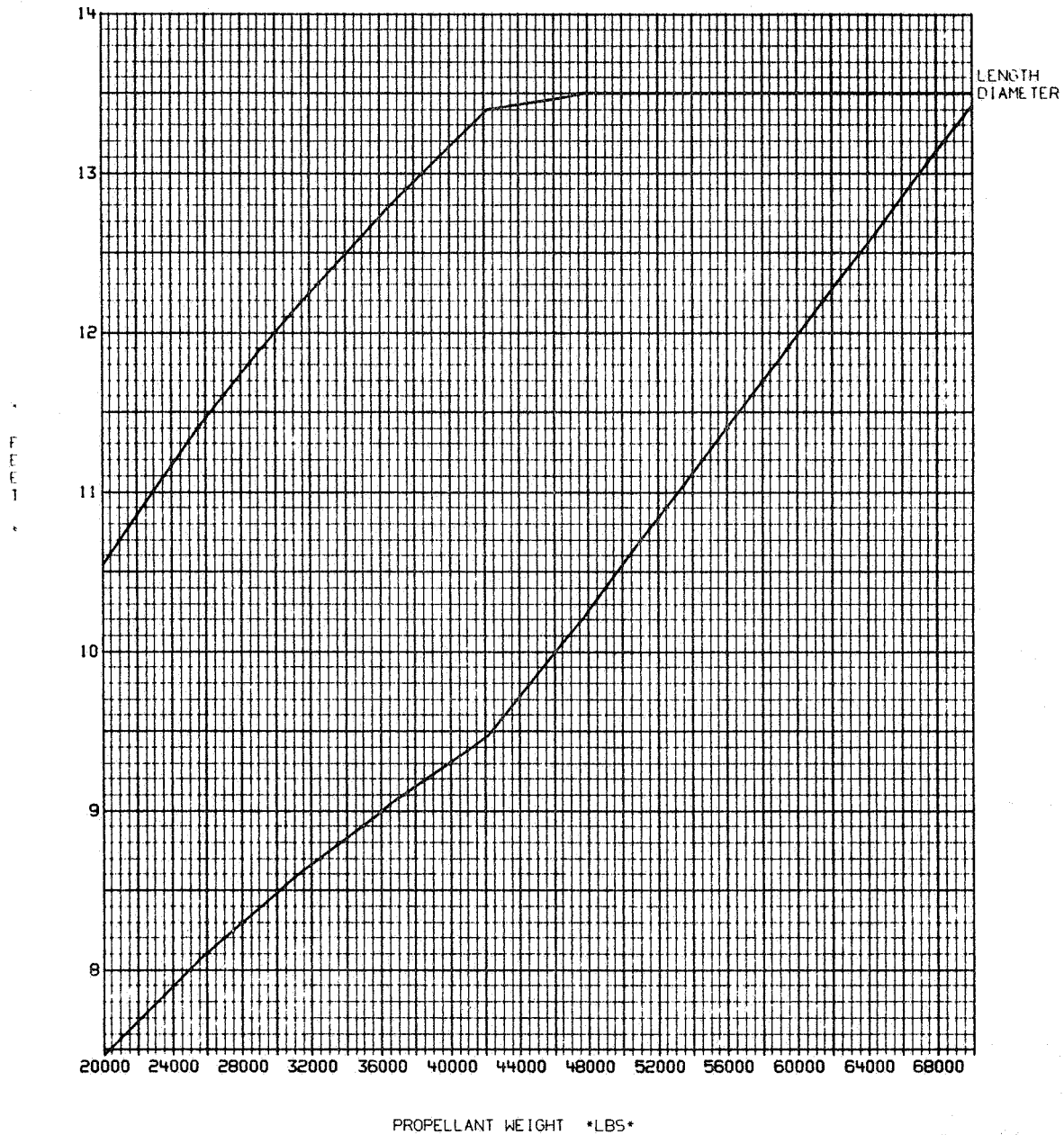


Figure 2-43

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

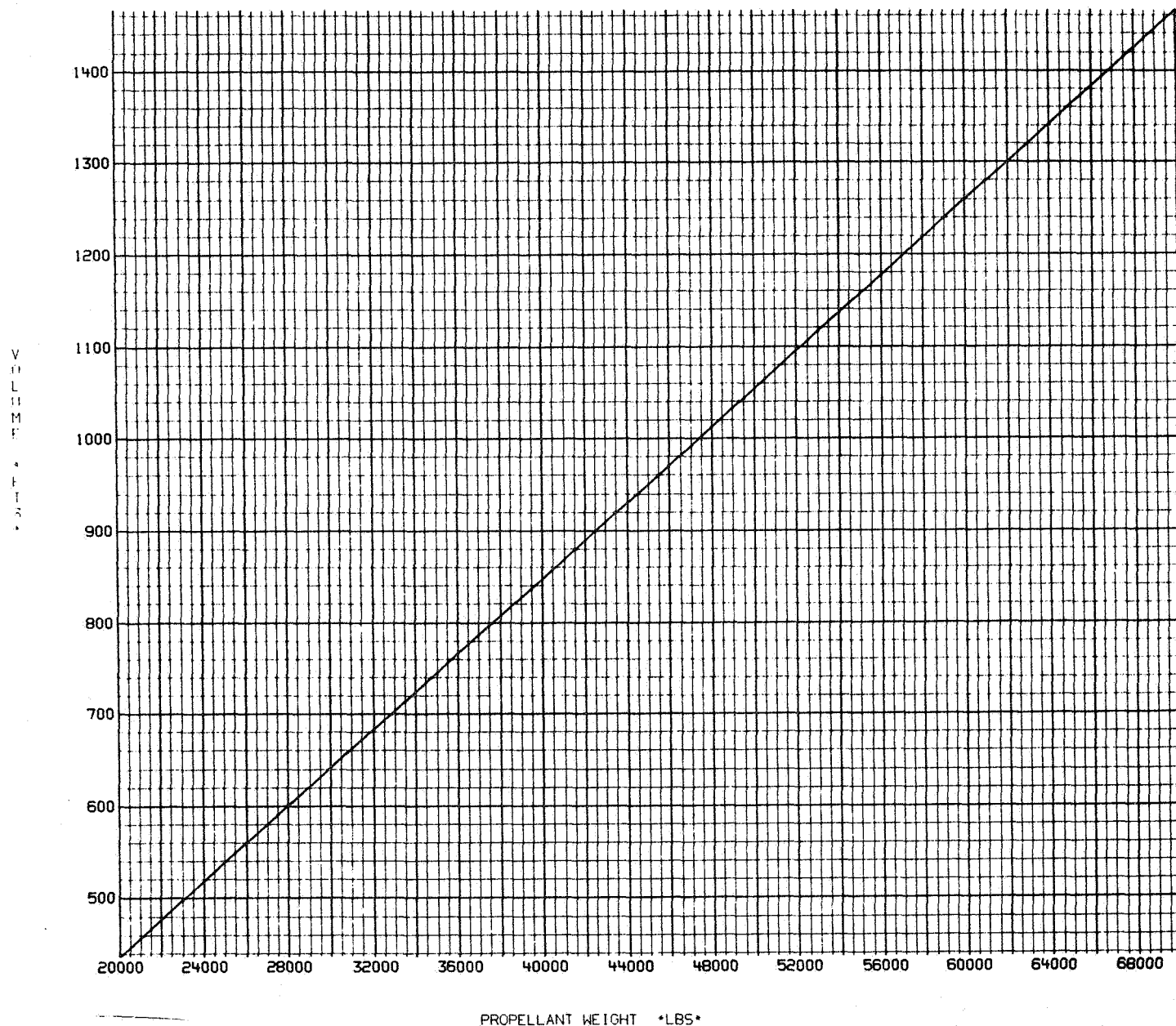


Figure 2-44

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

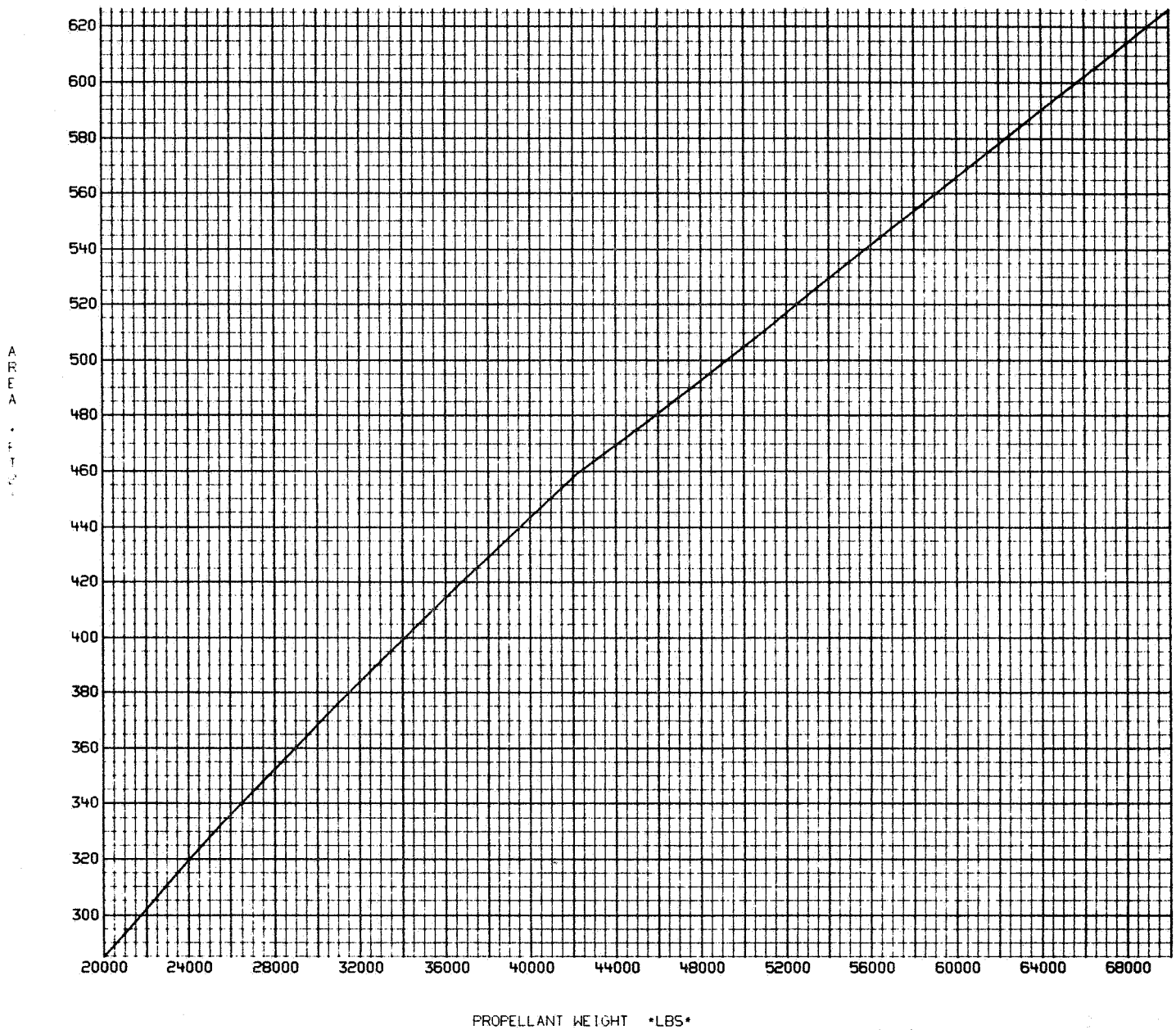


Figure 2-45

AREA OF CYLINDER * 0.01

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

479.4 SEC. SPECIFIC IMPULSE

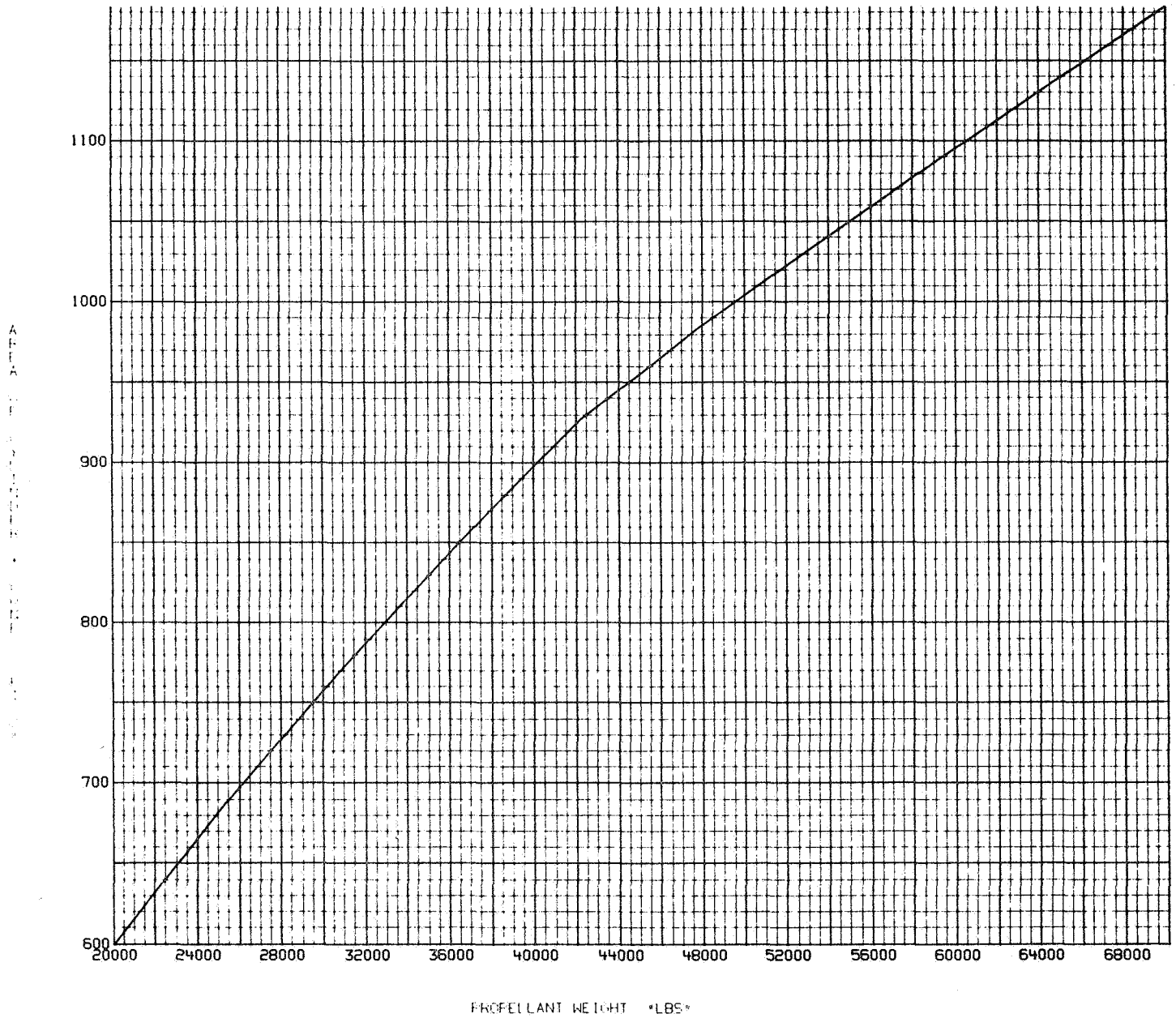


Figure 2-46

STAGE LENGTH

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

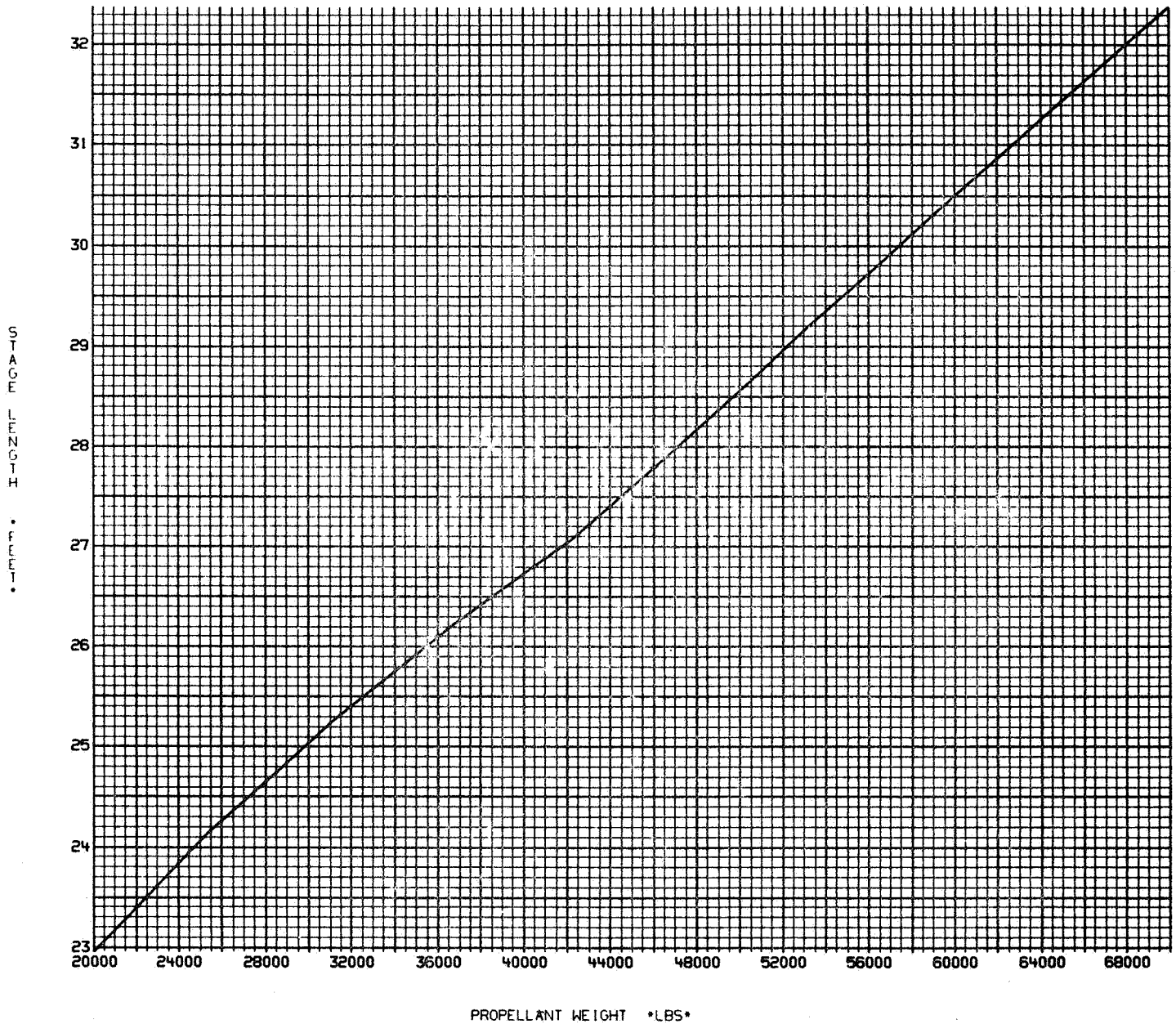


Figure 2-47

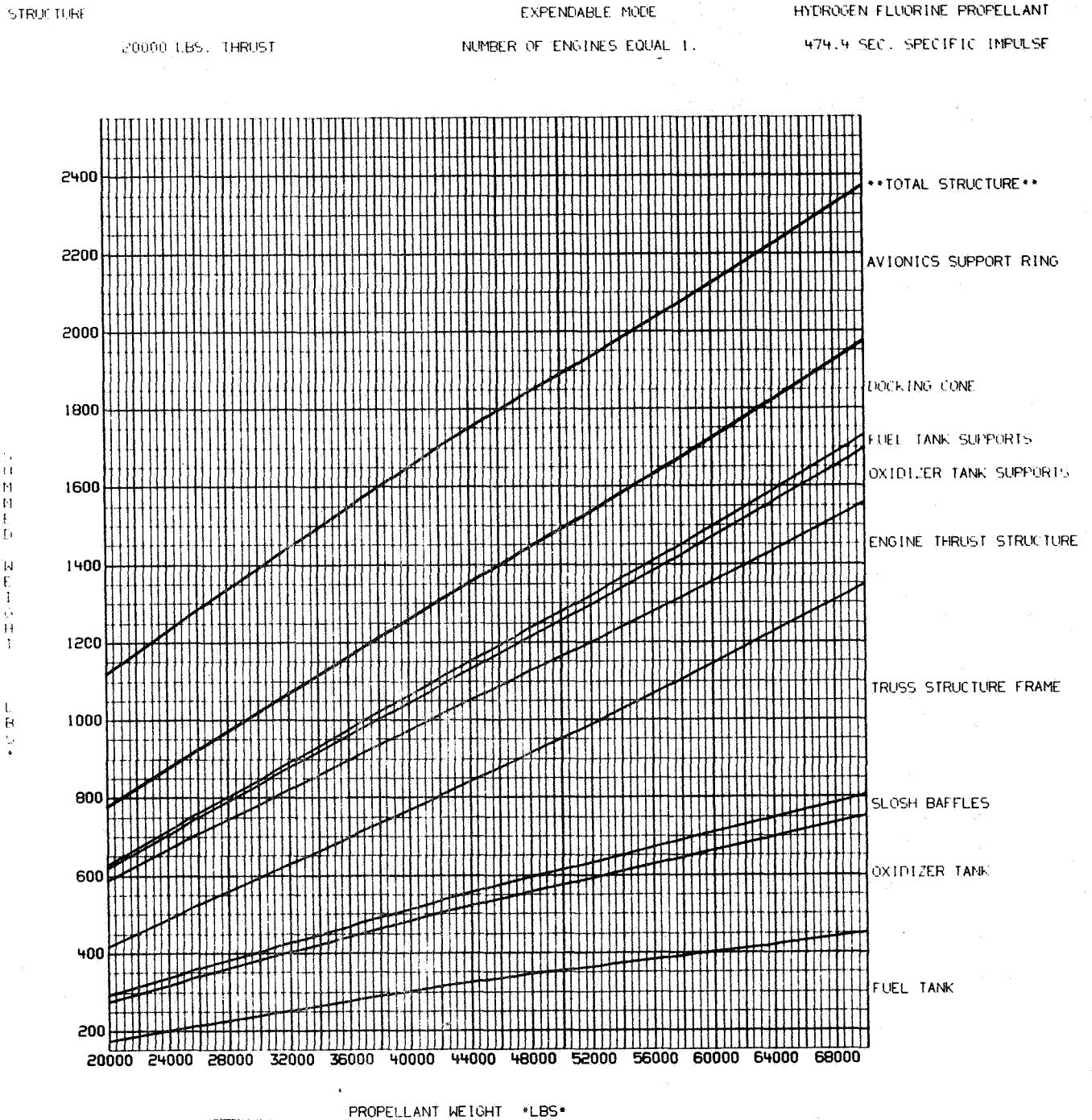


Figure 2-48

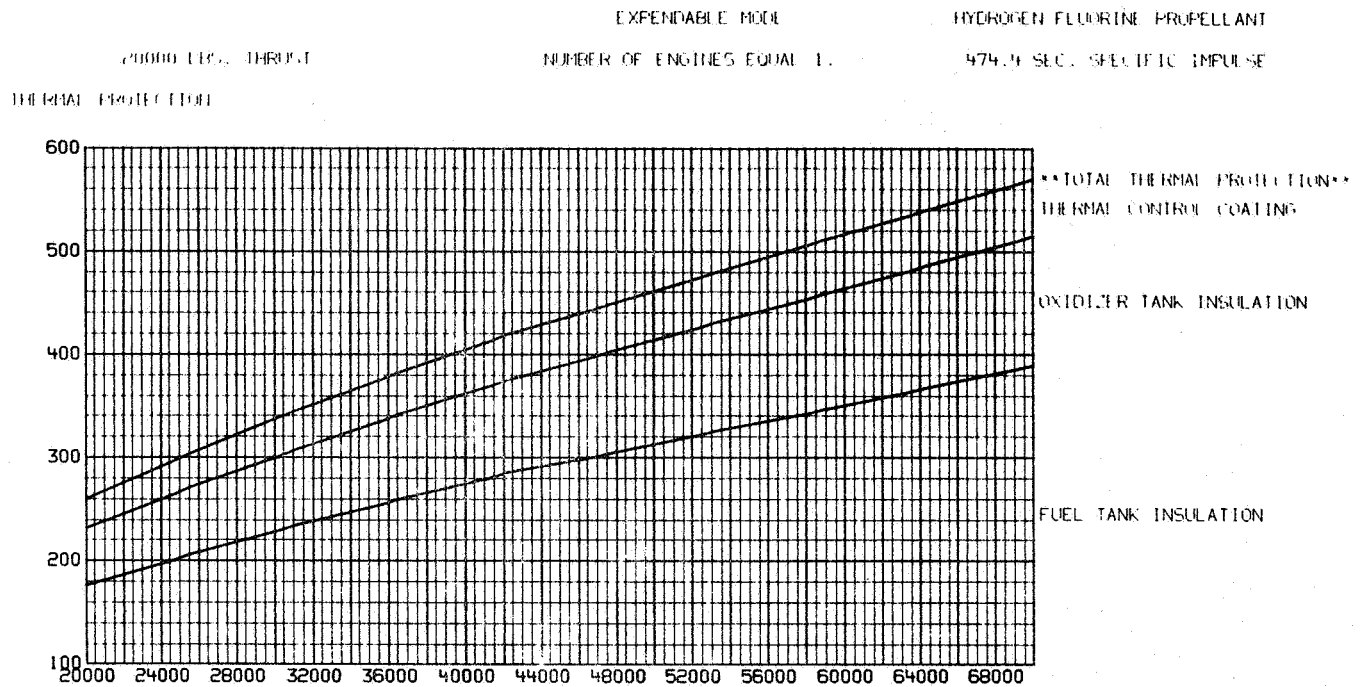


Figure 2-49

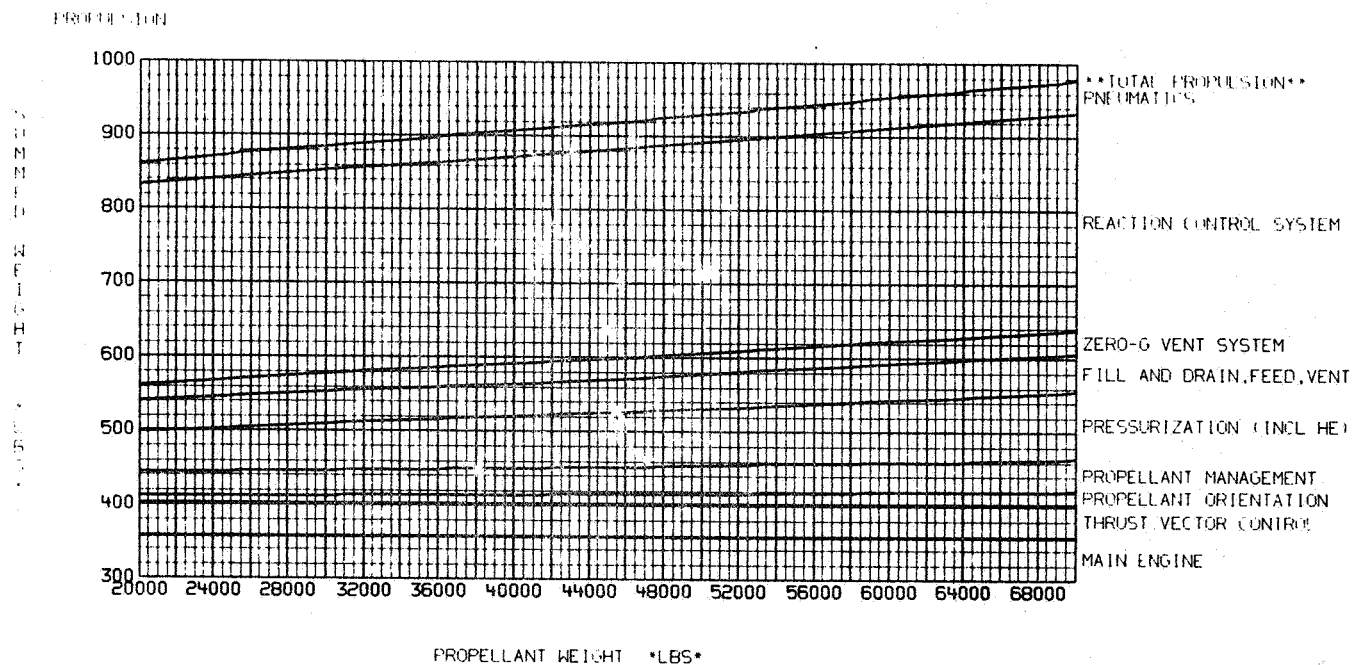


Figure 2-50

AVIONICS AND ELECTRICAL POWER

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

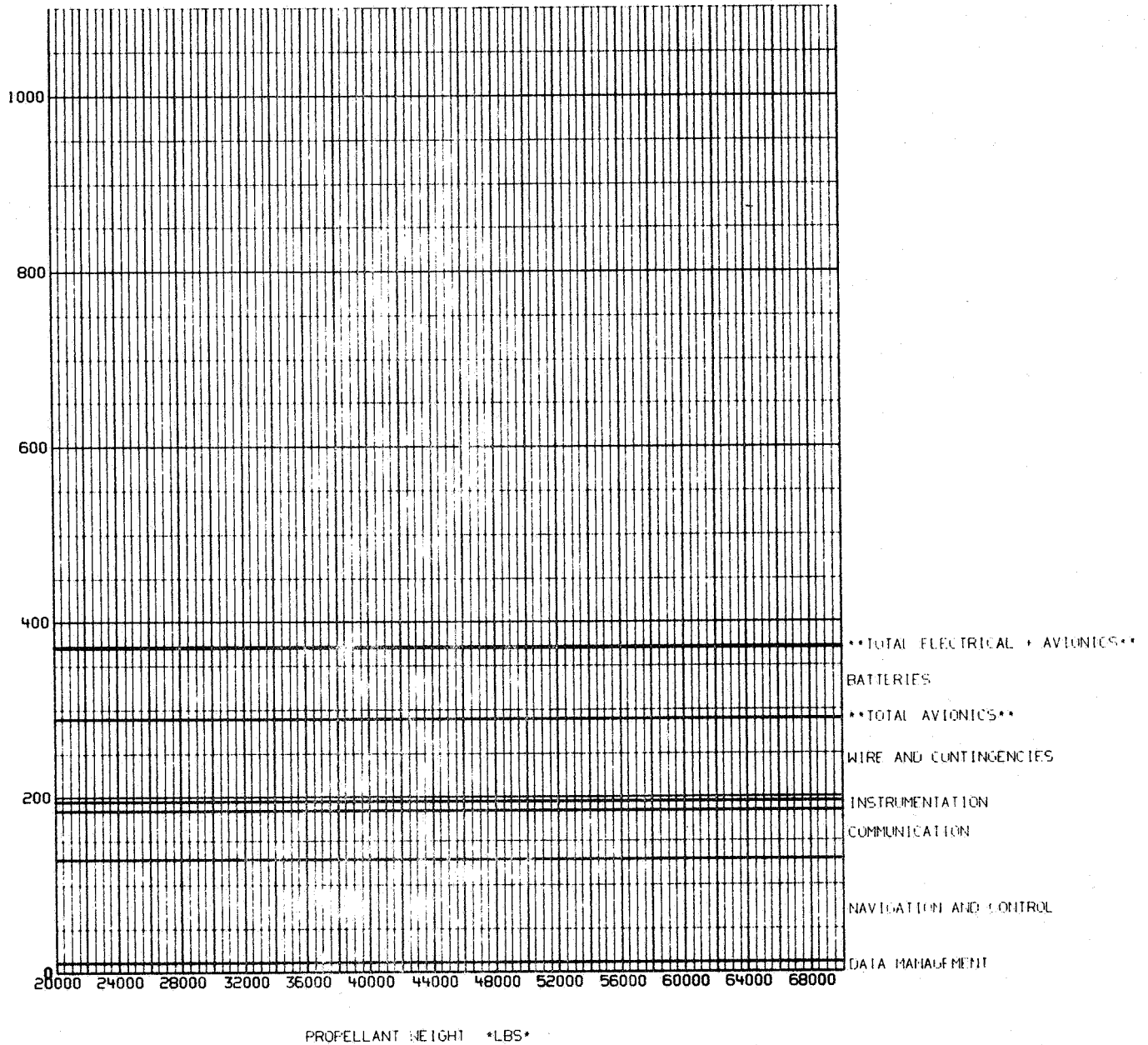


Figure 2-51

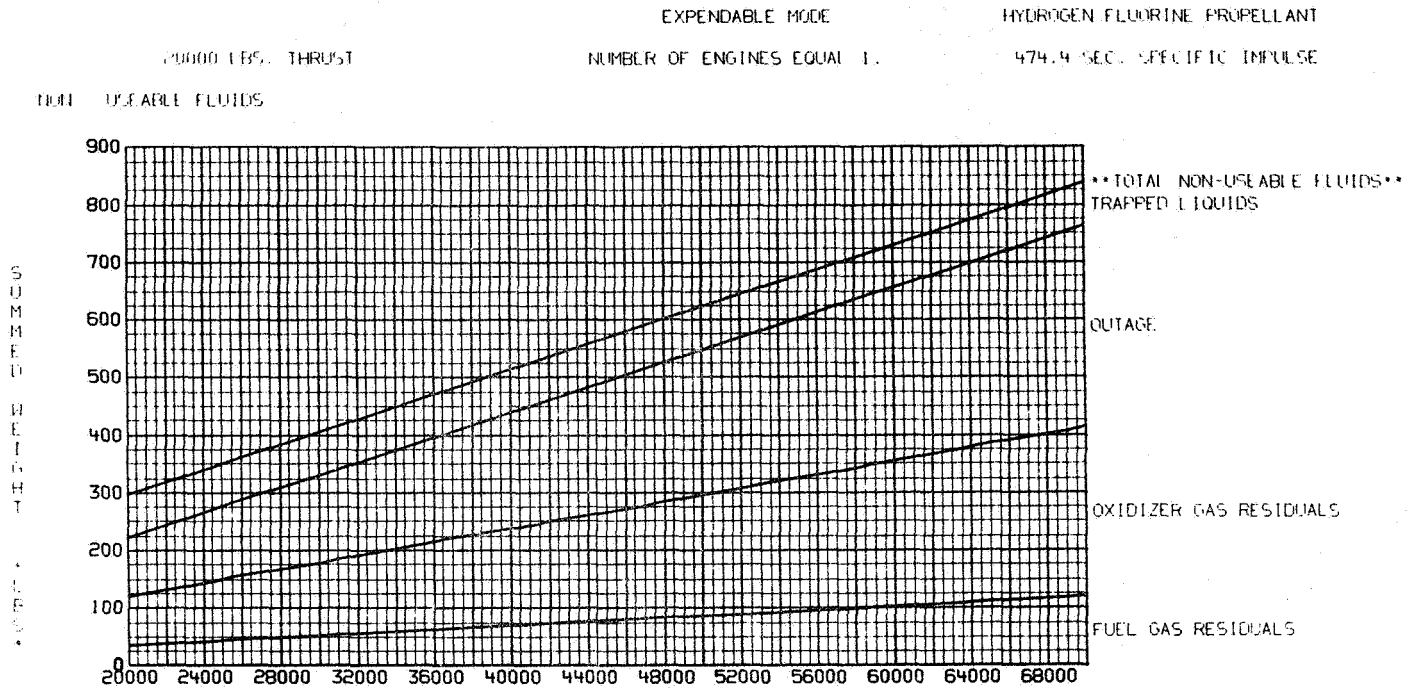


Figure 2-52

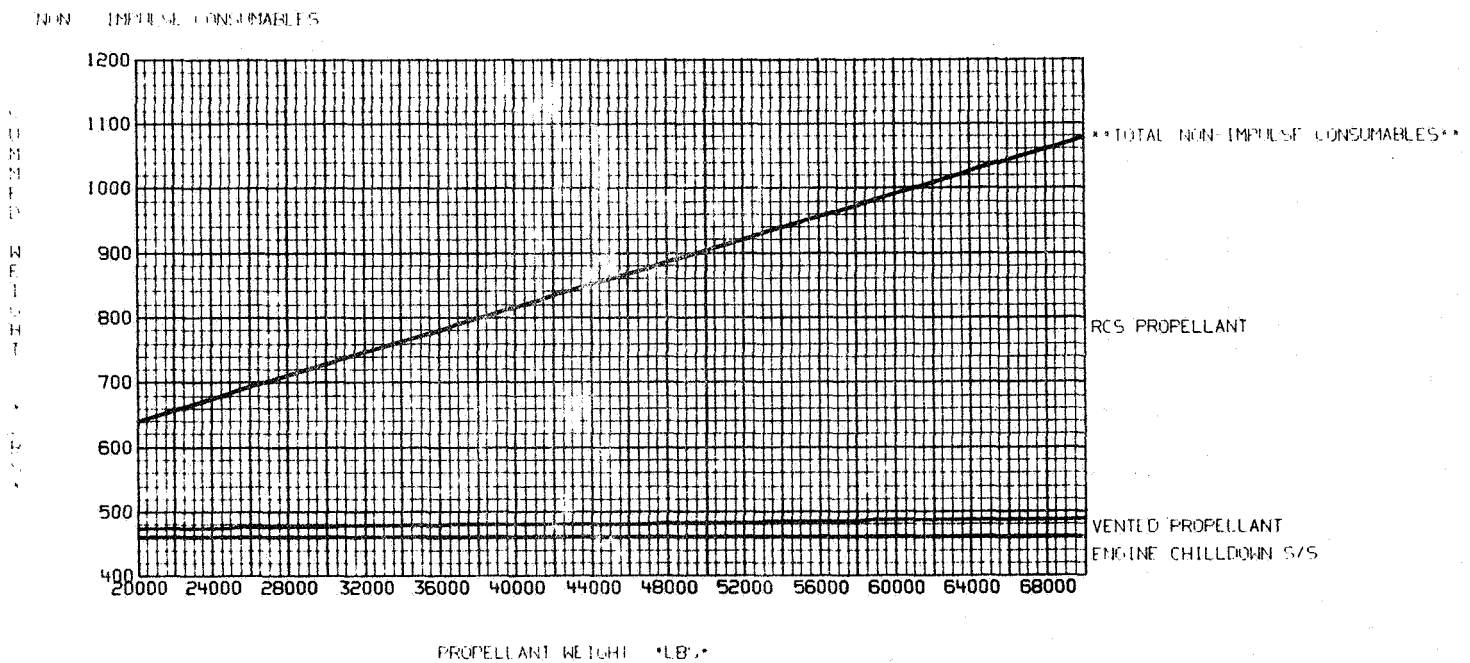


Figure 2-53

ADVANCED TUG SYSTEM WEIGHTS
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

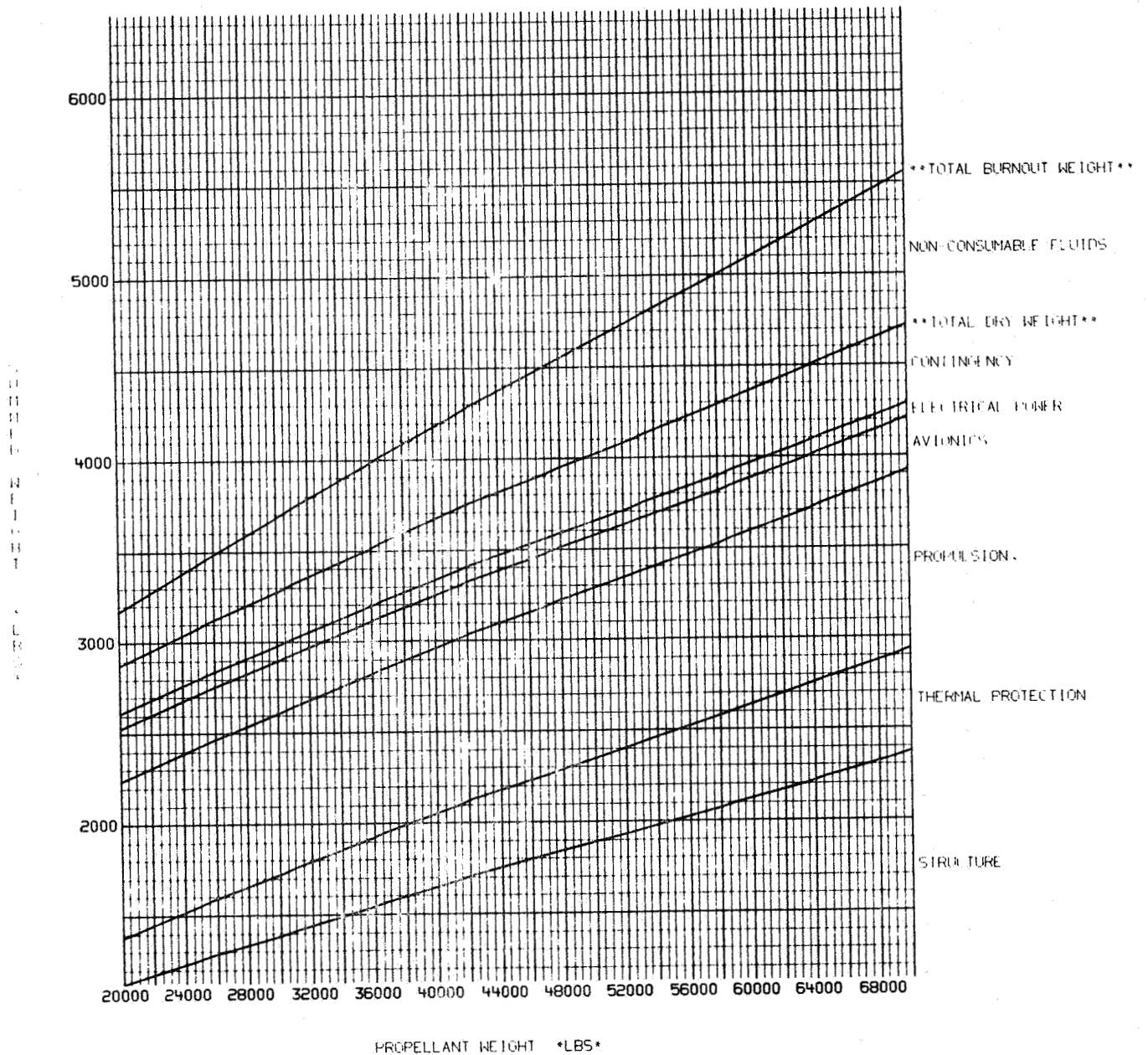


Figure 2-54

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

HYDROGEN FLUORINE PROPELLANT

474.4 SEC. SPECIFIC IMPULSE

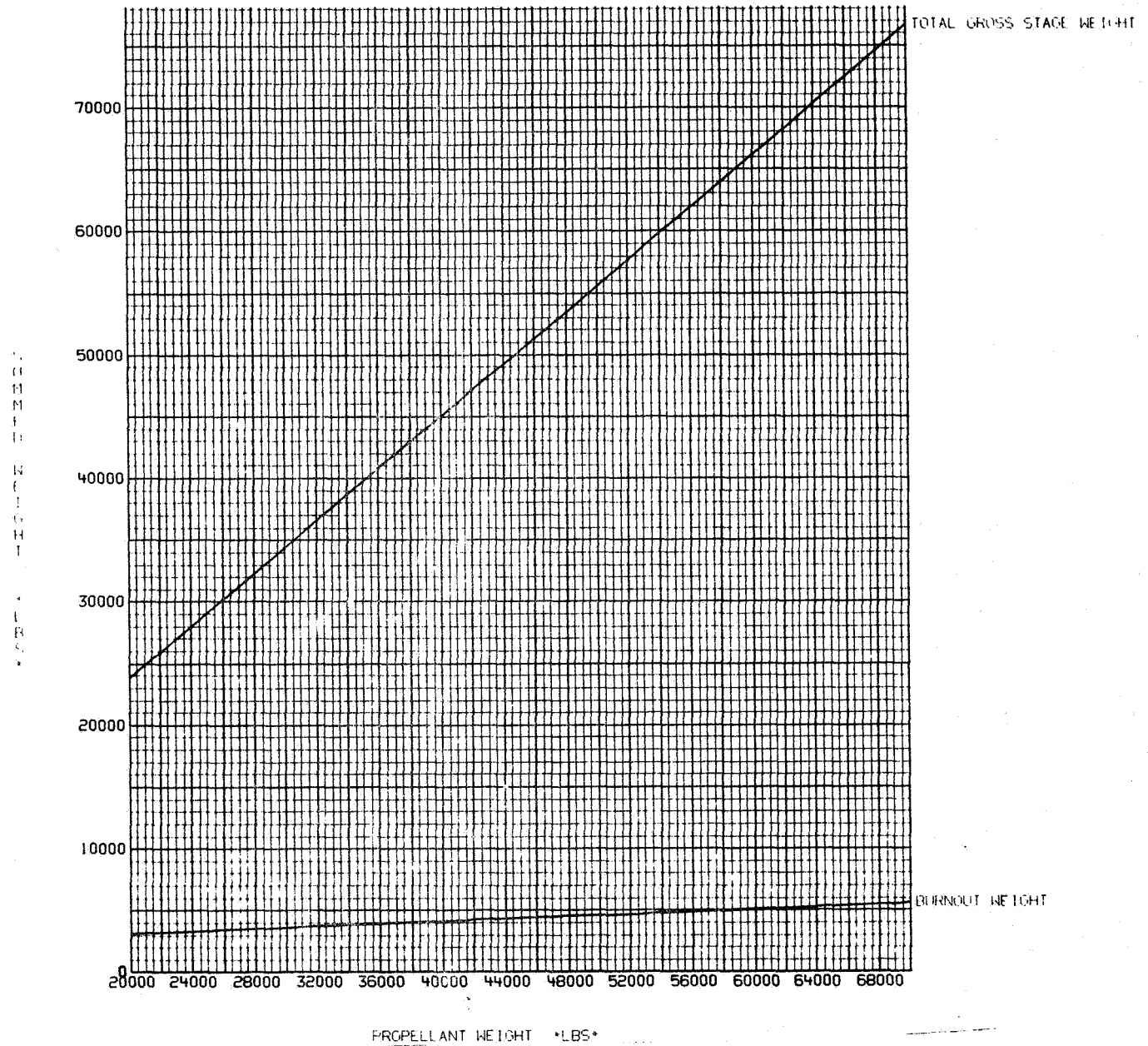


Figure 2-55

TAMBA PRIME BASED ON TOTAL ORBS STAGE WEIGHT

EXPENDABLE MODE

HYDROGEN FLUORINE PROPELLANT

40000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

474.4 SEC. SPECIFIC IMPULSE

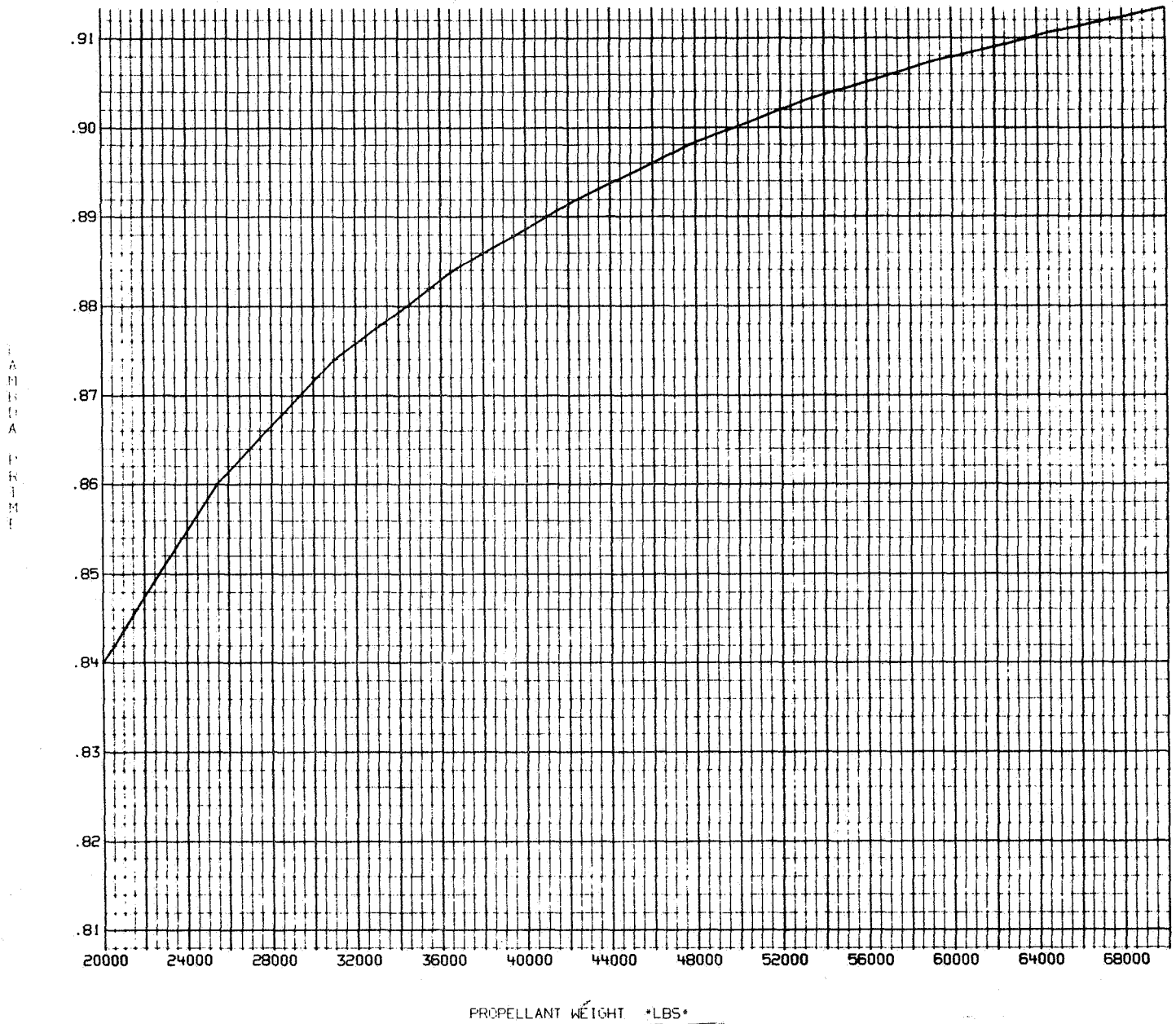


Figure 2-56

LAMBDA PRIME BASED ON BURNDOUT HEIGHT AND IMPULSE PROP. EXPENDABLE MODE
20000 LBS. THRUST
NUMBER OF ENGINES EQUAL 1.
HYDROGEN FLUORINE PROPELLANT
474.4 SEC. SPECIFIC IMPULSE

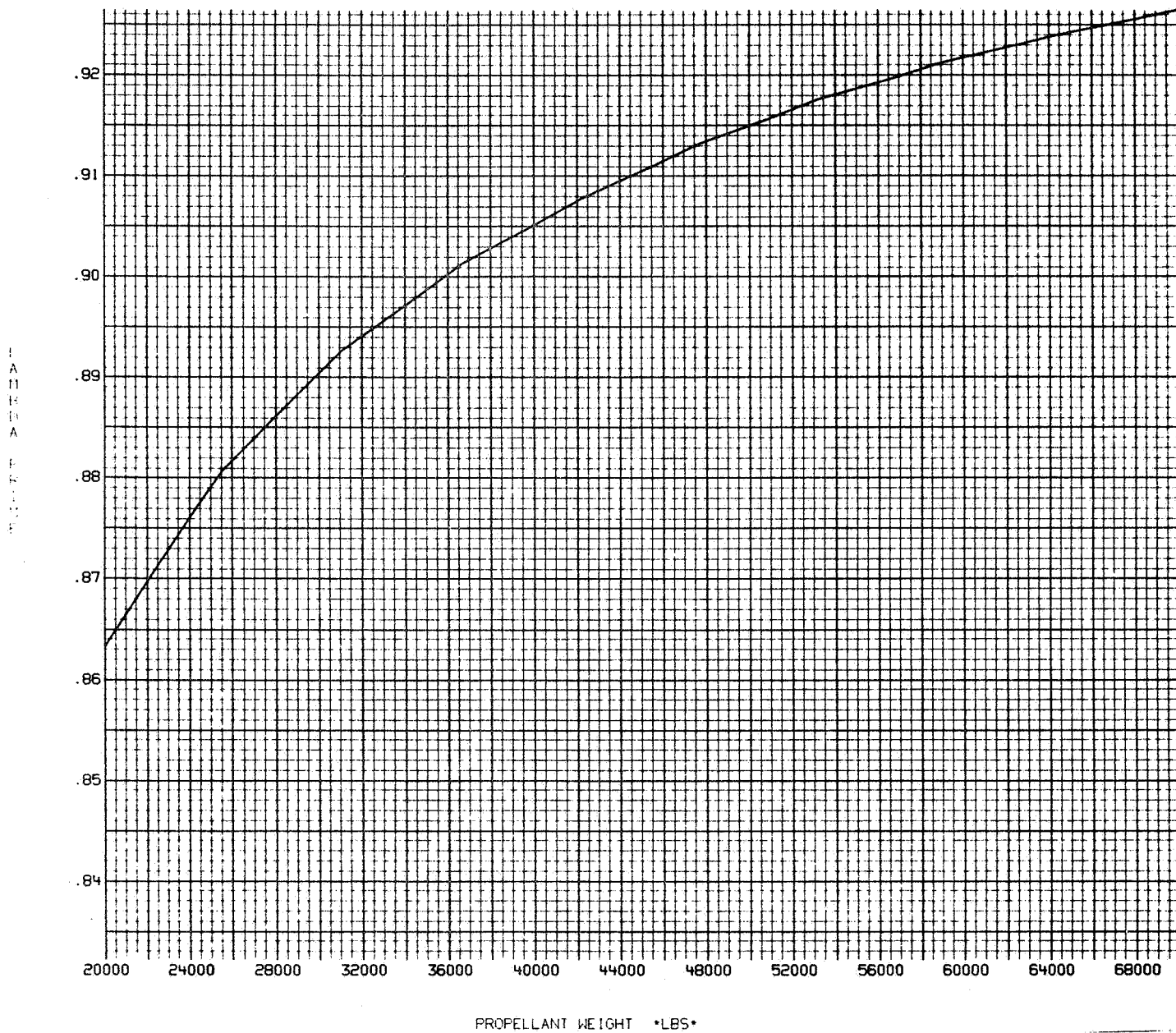


Figure 2-57

STRUCTURE

REUSEABLE MODE

FLOX METHANE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

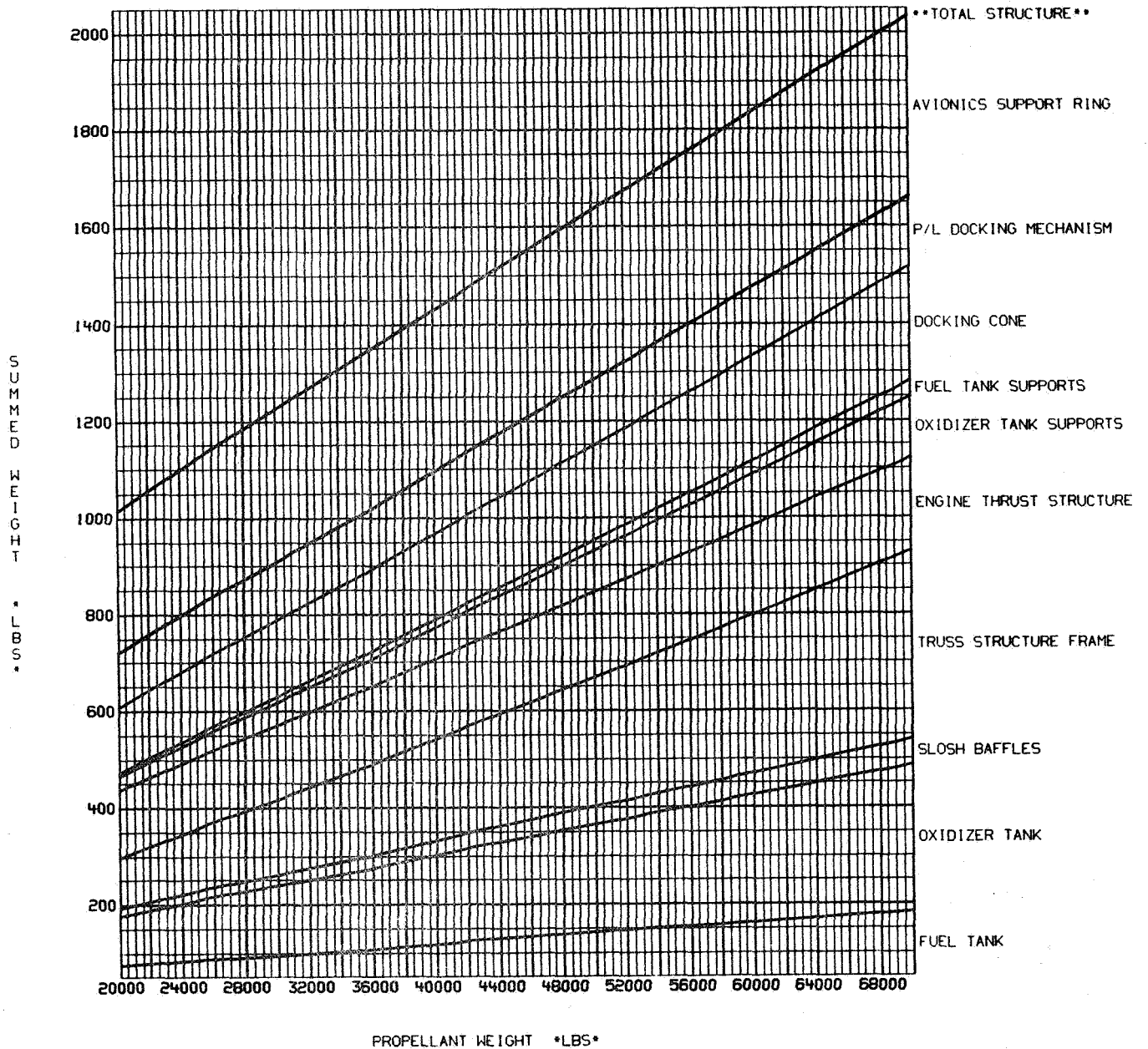


Figure 2-58

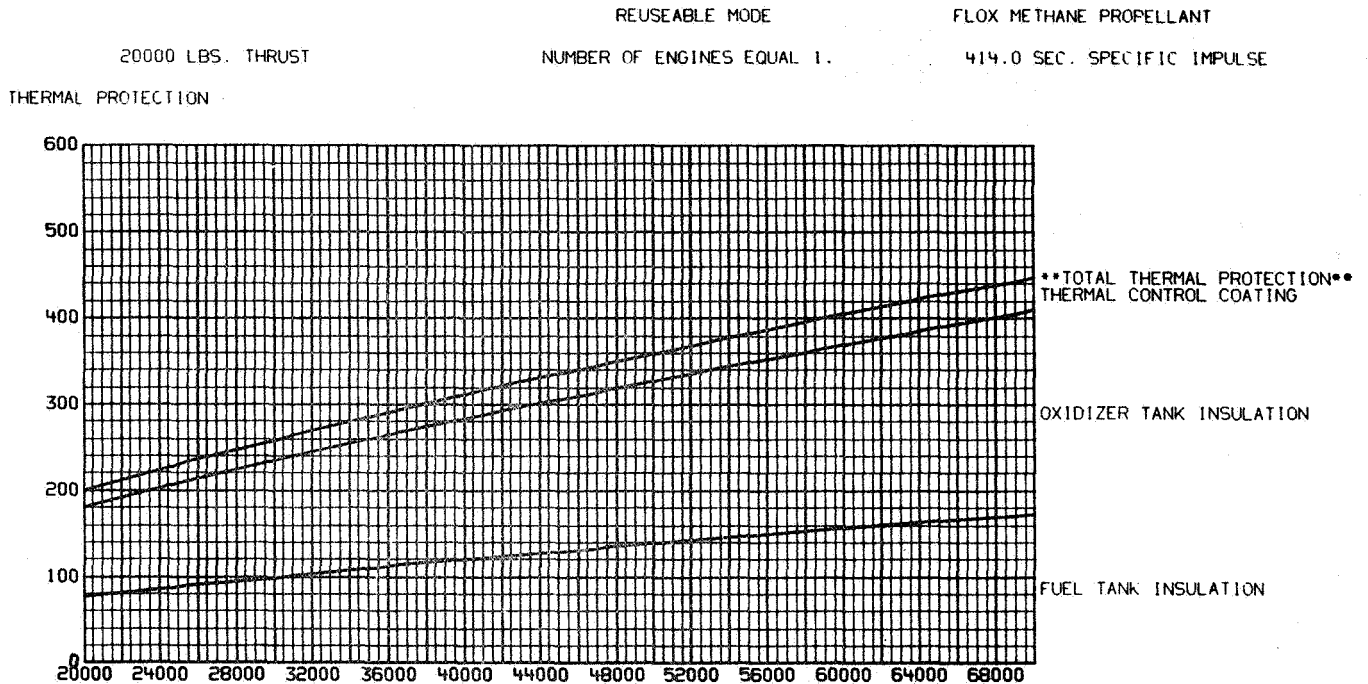


Figure 2-59

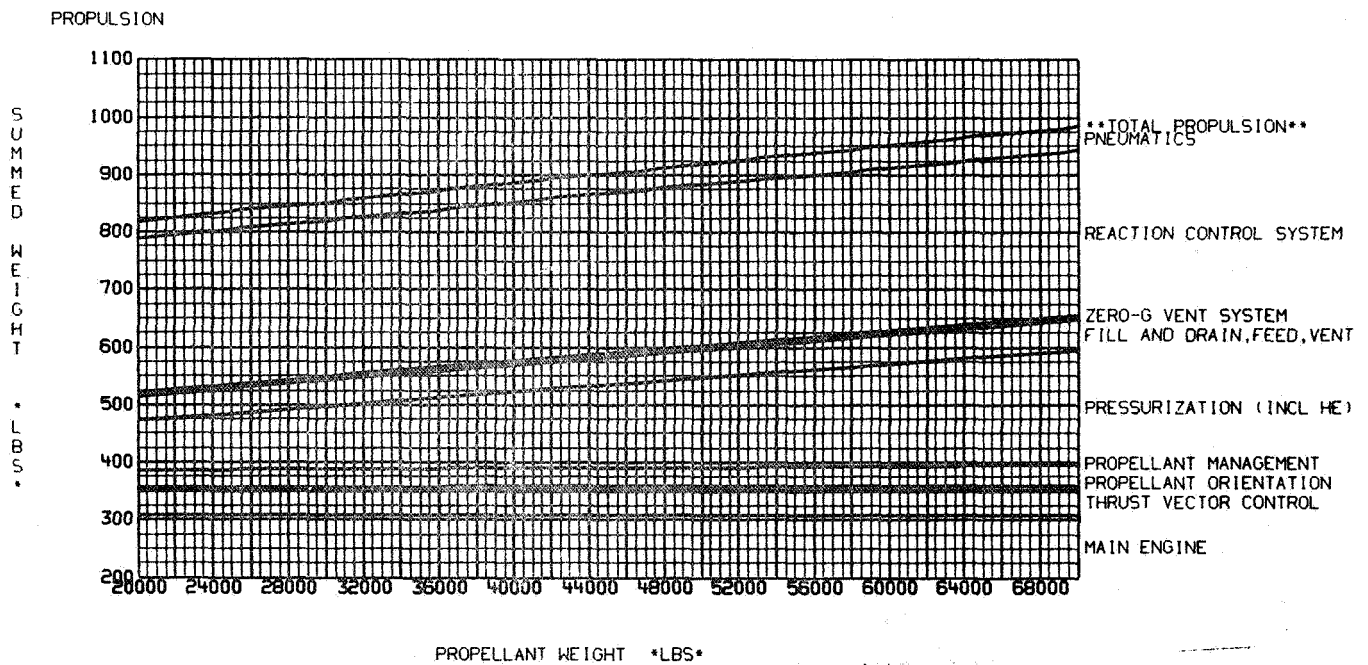


Figure 2-60

AVIONICS AND ELECTRICAL POWER

REUSEABLE MODE

FLOX METHANE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

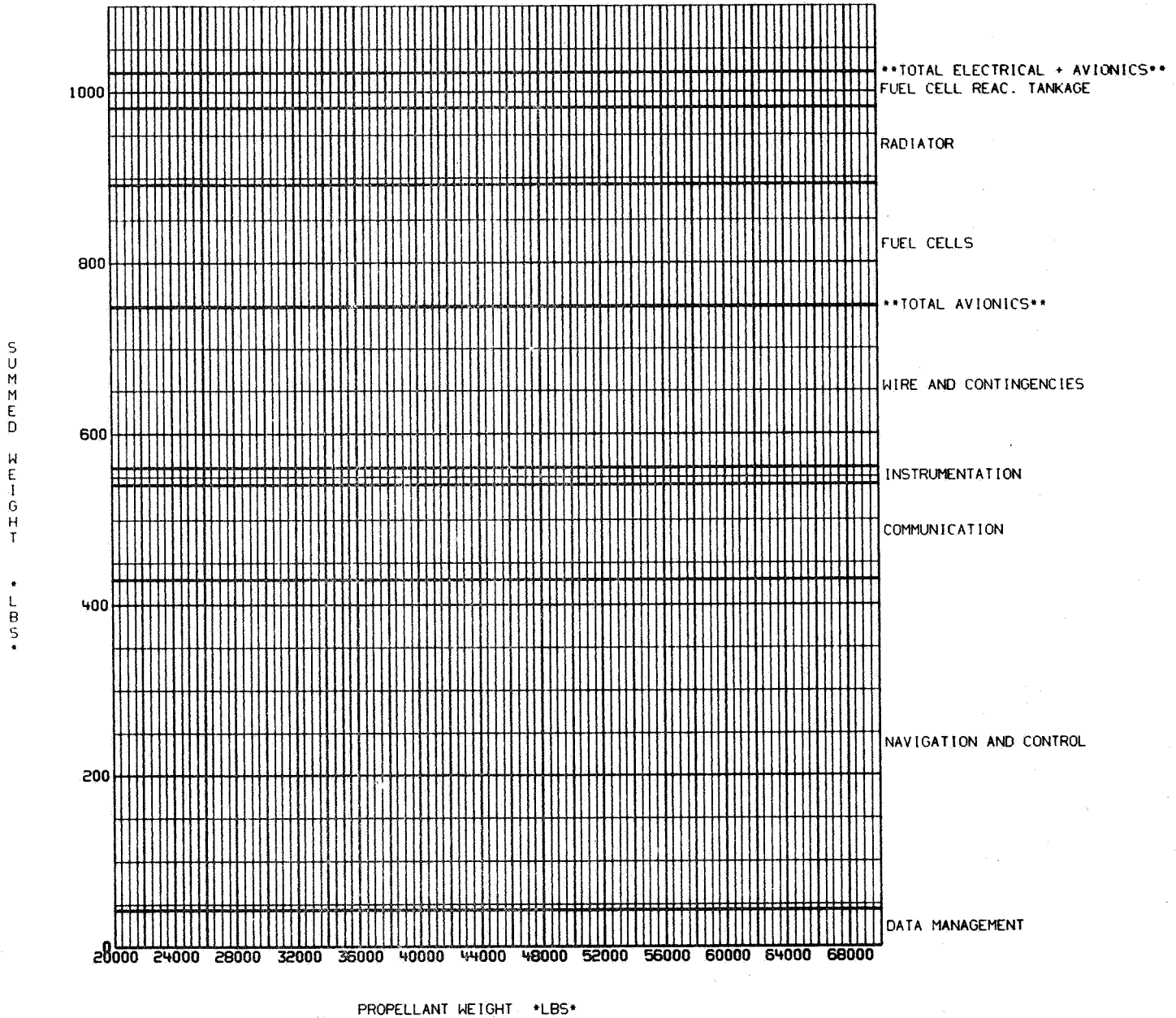


Figure 2-61

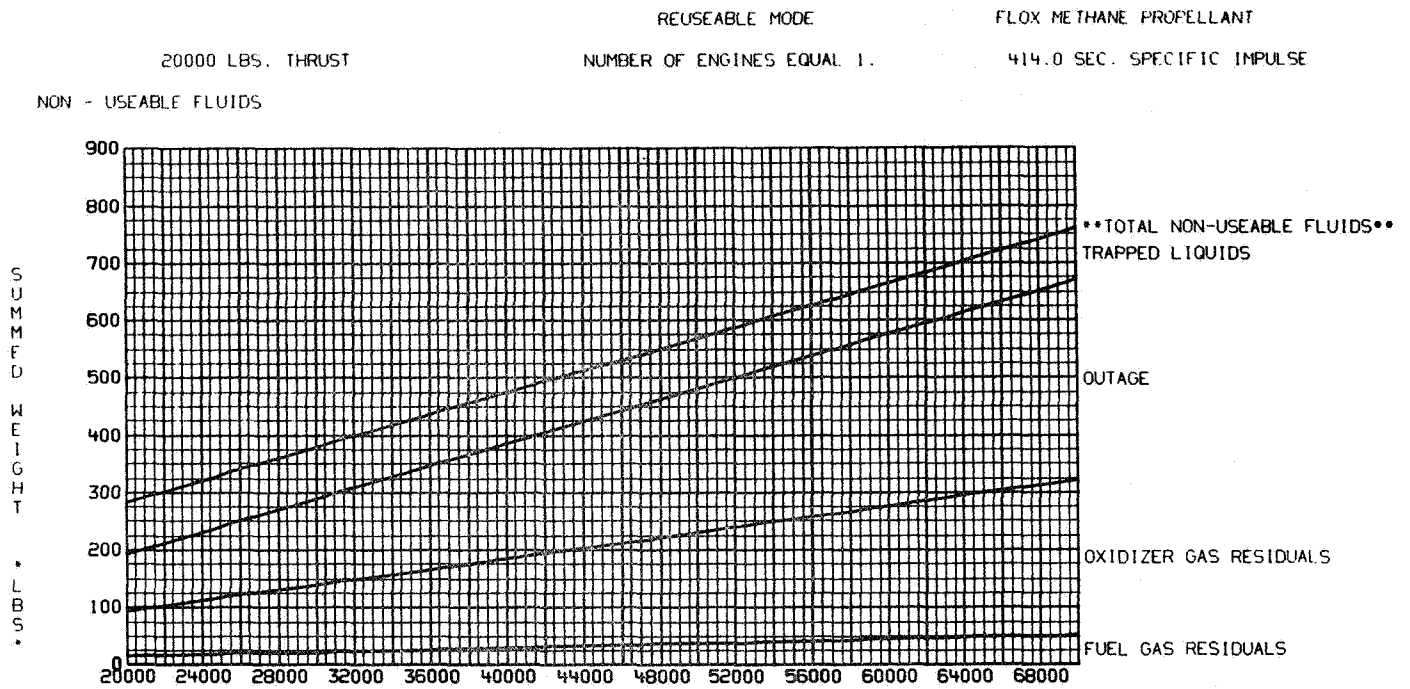


Figure 2-62

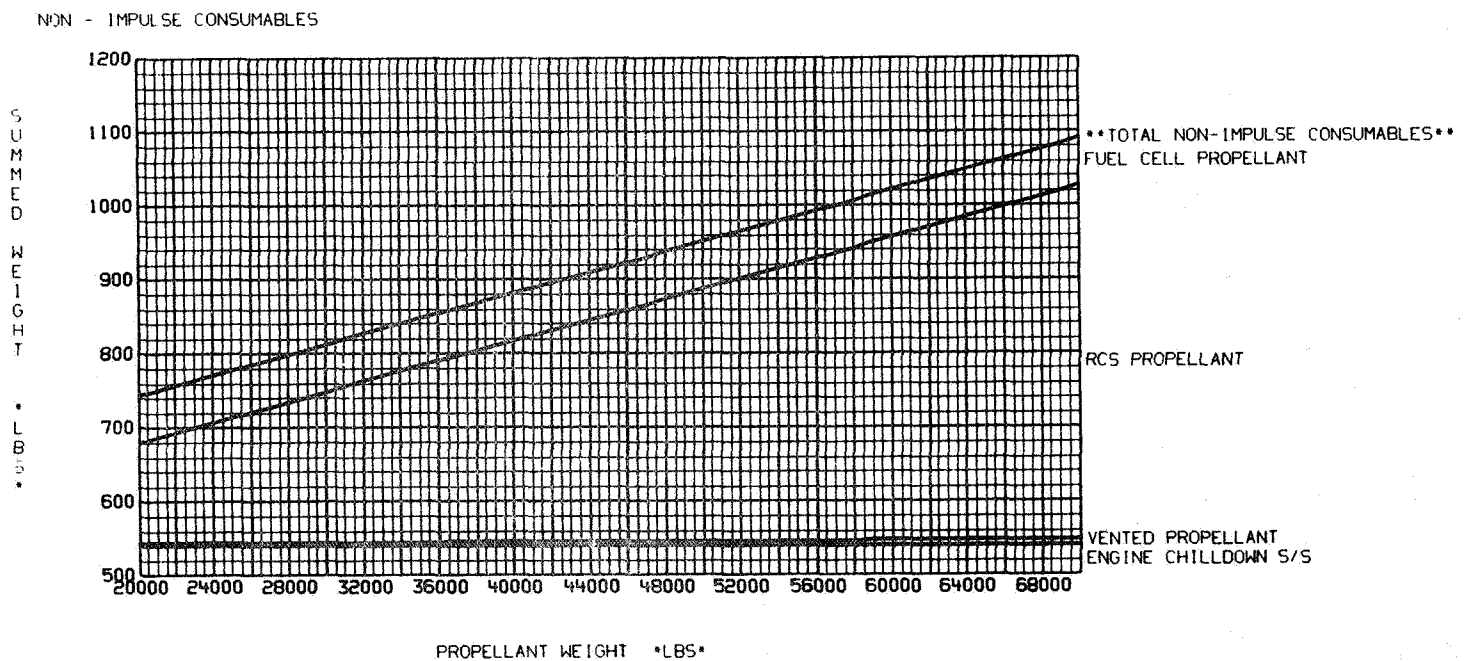


Figure 2-63

ADVANCED TUG SYSTEM WEIGHTS

REUSEABLE MODE

FLOX METHANE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

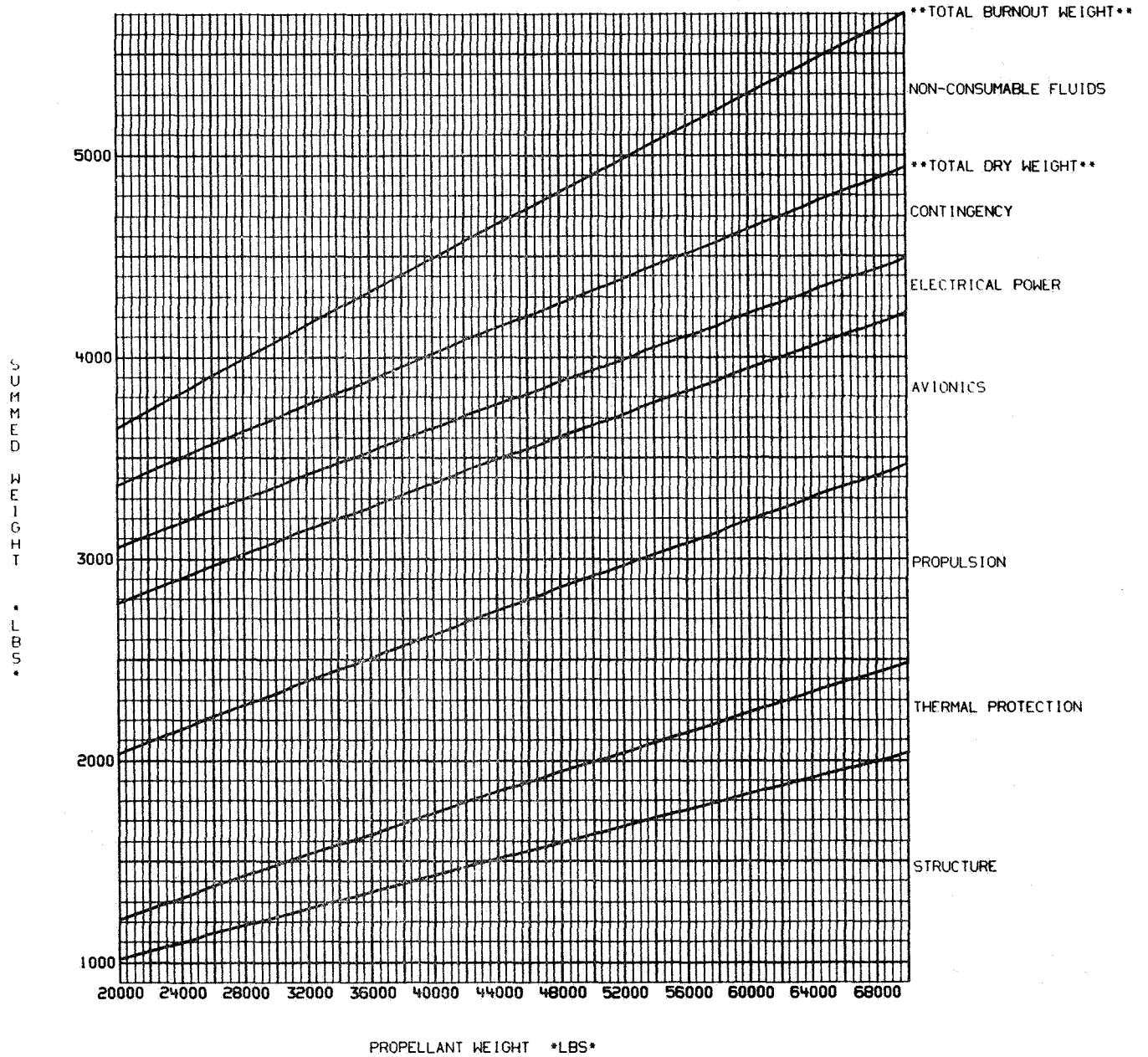


Figure 2-64

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

REUSEABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

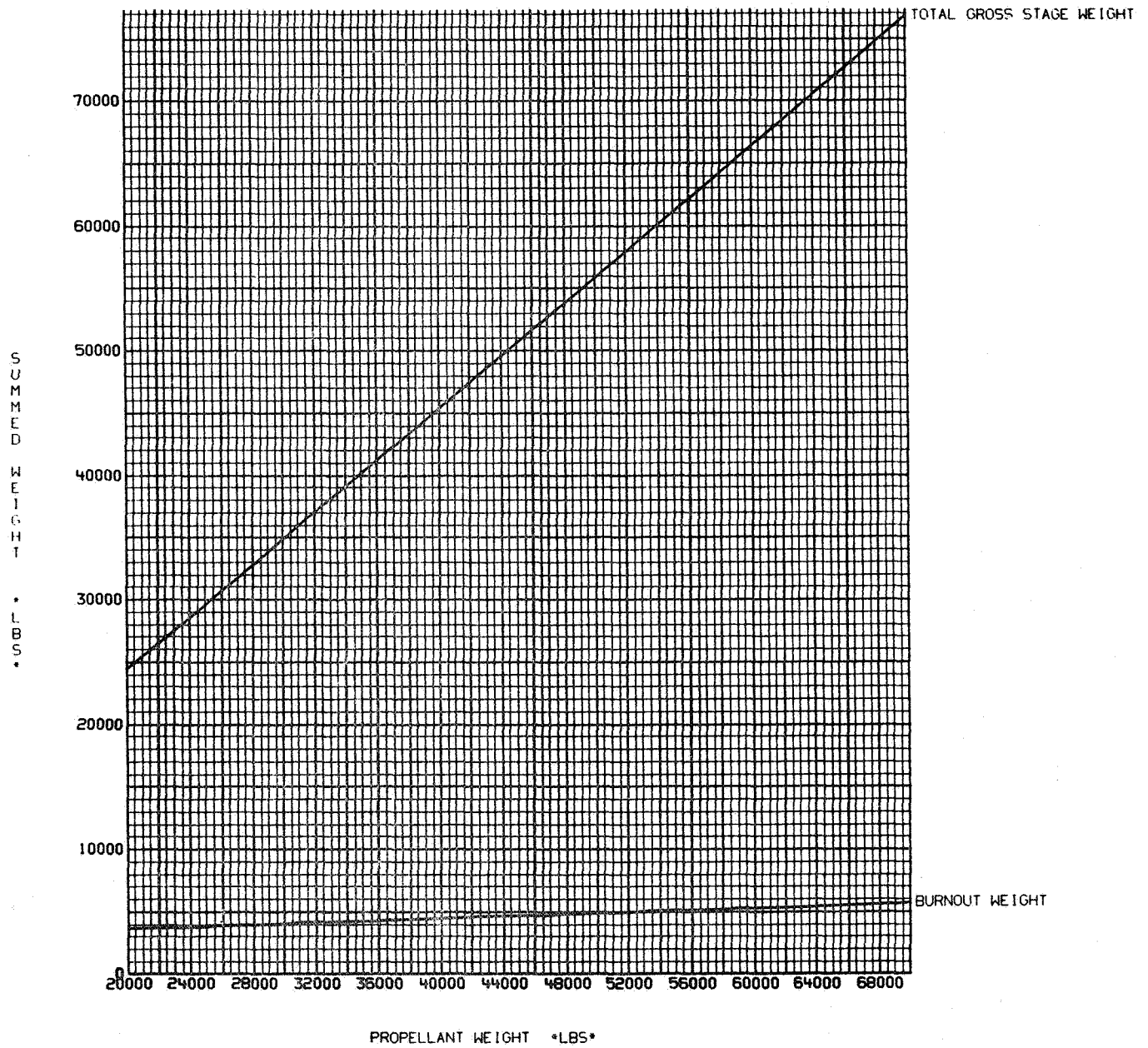


Figure 2-65

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT

REUSEABLE MODE

FLOX METHANE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

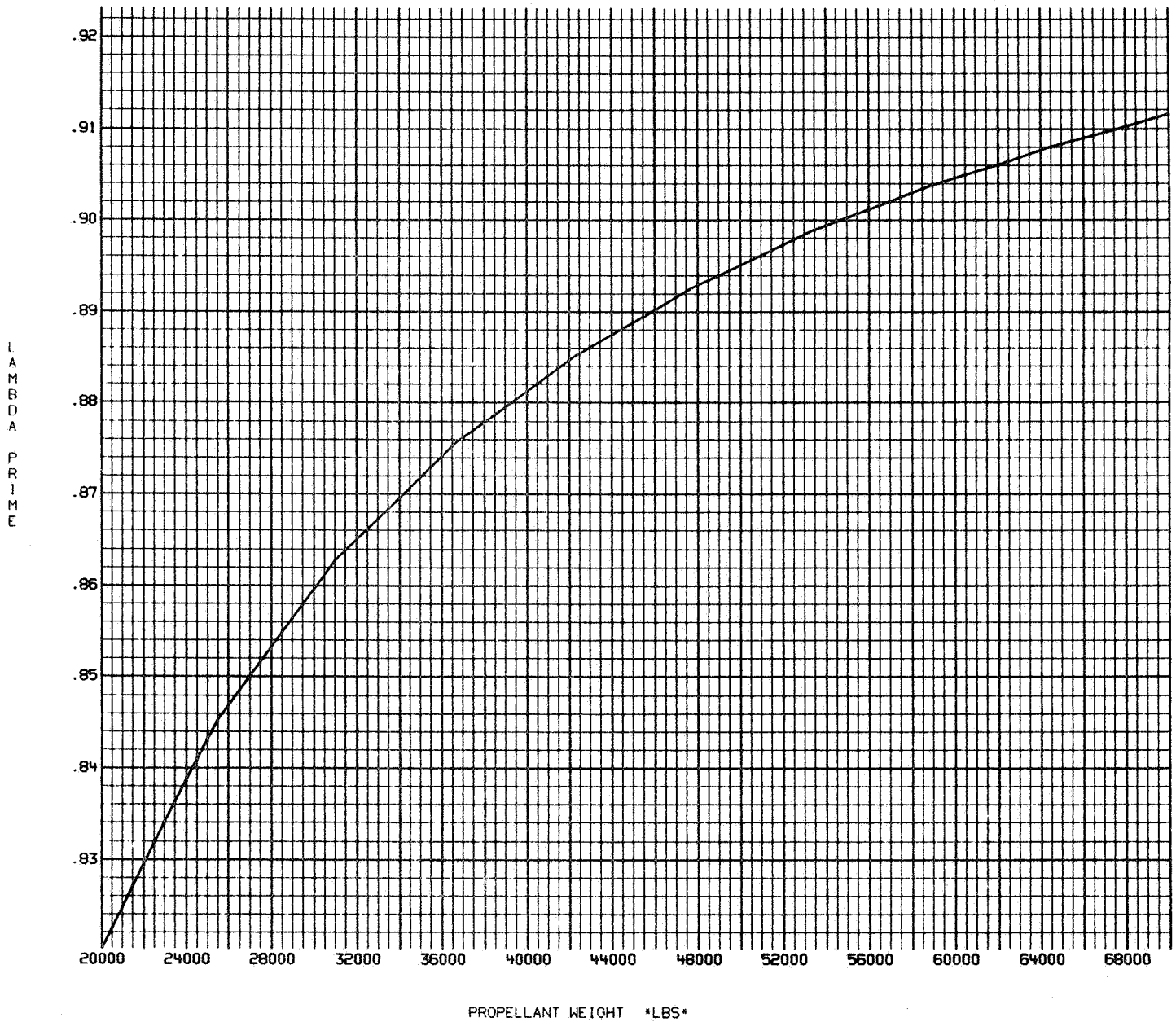


Figure 2-66

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP. REUSABLE MODE FLOX METHANE PROPELLANT
20000 LBS. THRUST NUMBER OF ENGINES EQUAL 1. 914.0 SEC. SPECIFIC IMPULSE

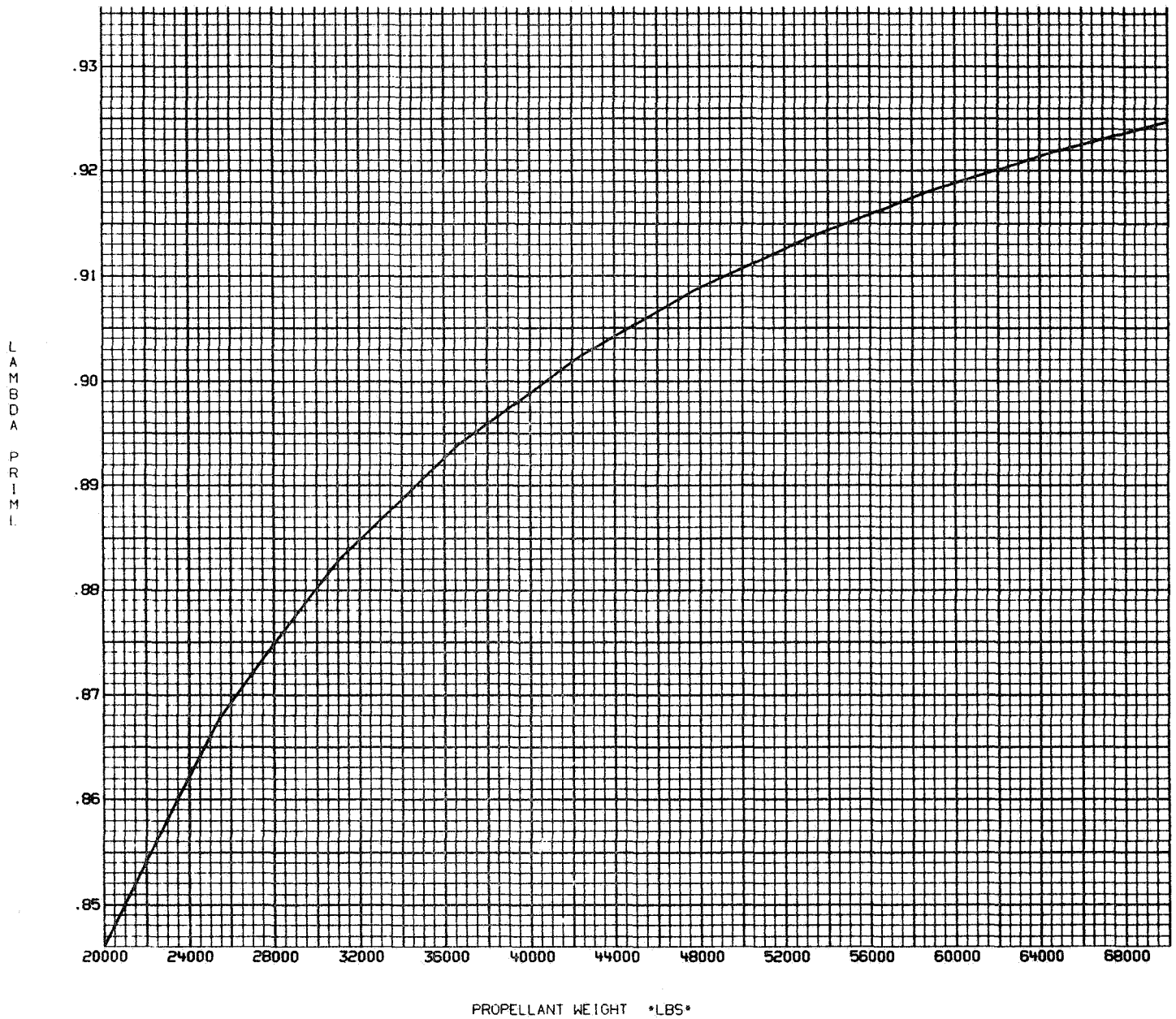


Figure 2-67

OXIDIZER TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

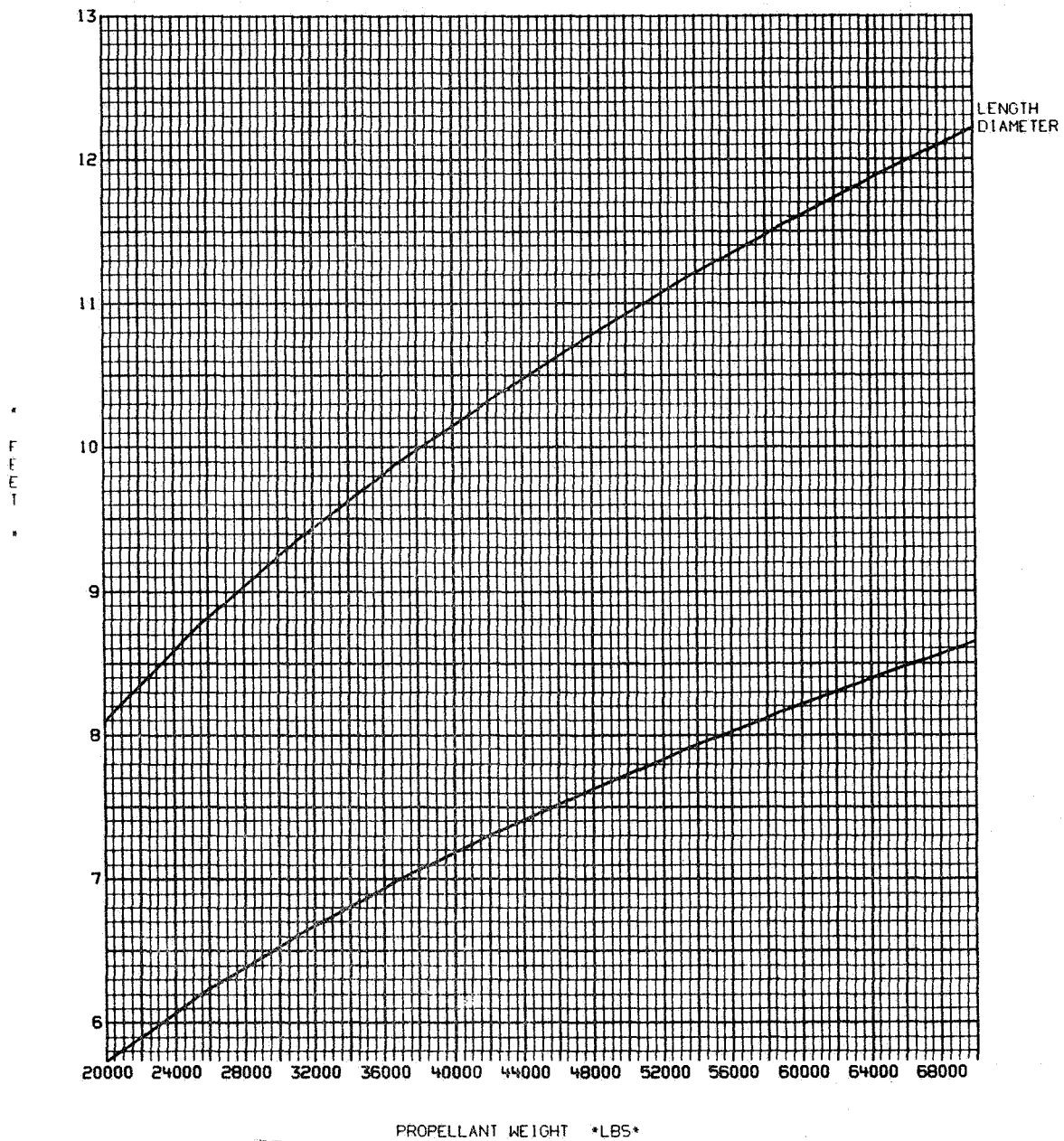


Figure 2-68

Oxidizer Tank

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

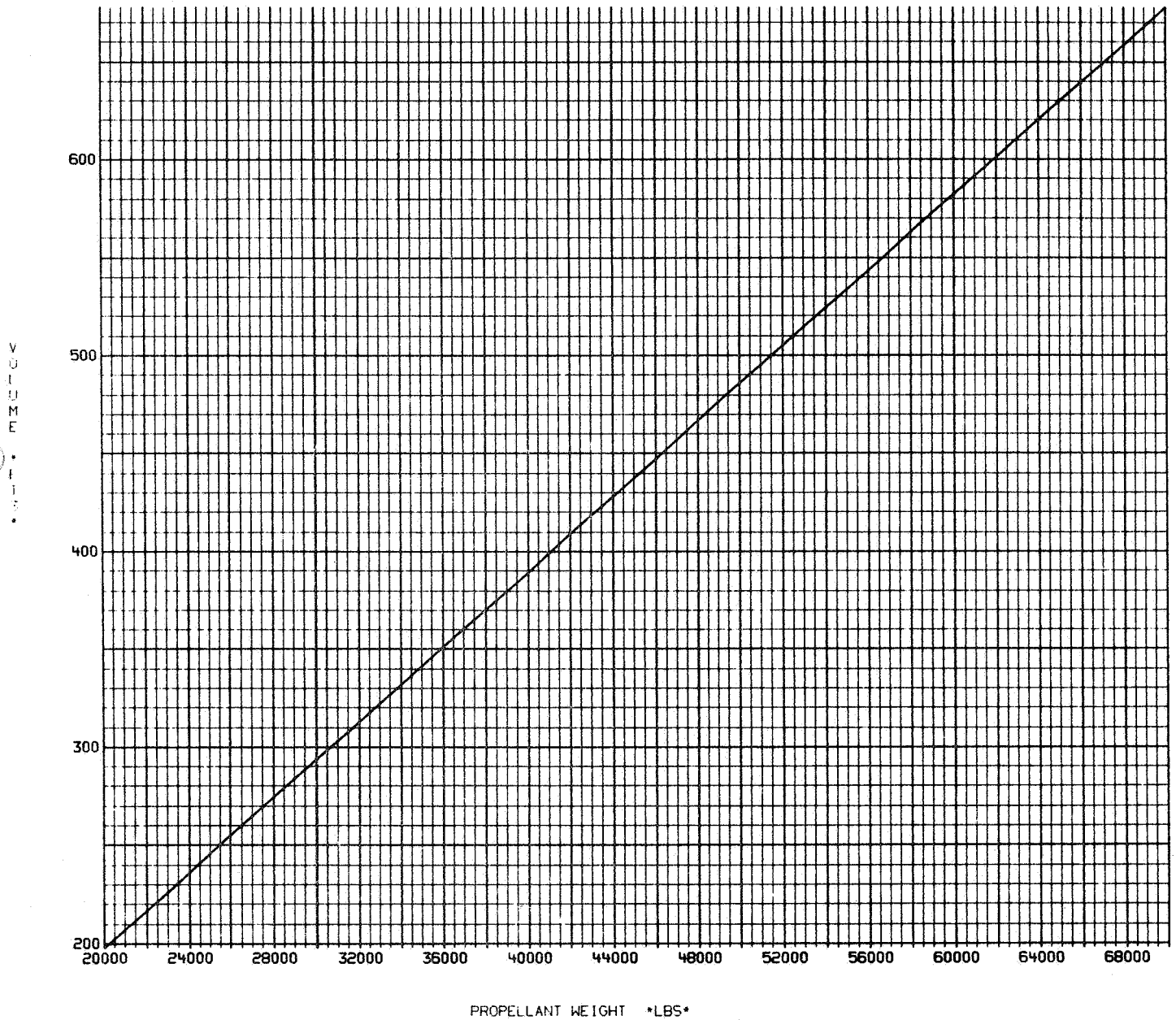


Figure 2-69

OXIDIZER TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

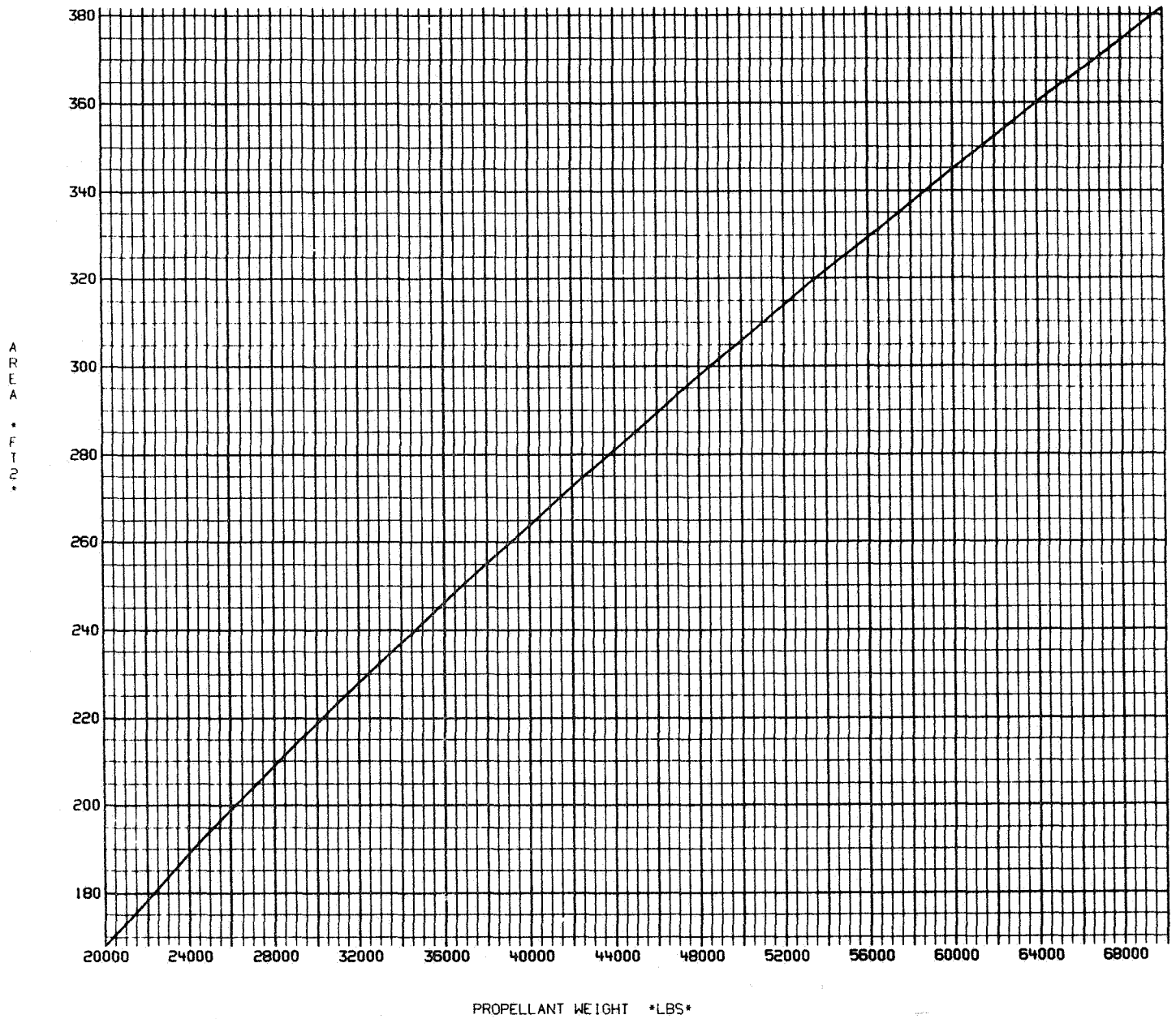


Figure 2-70

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

419.0 SEC. SPECIFIC IMPULSE

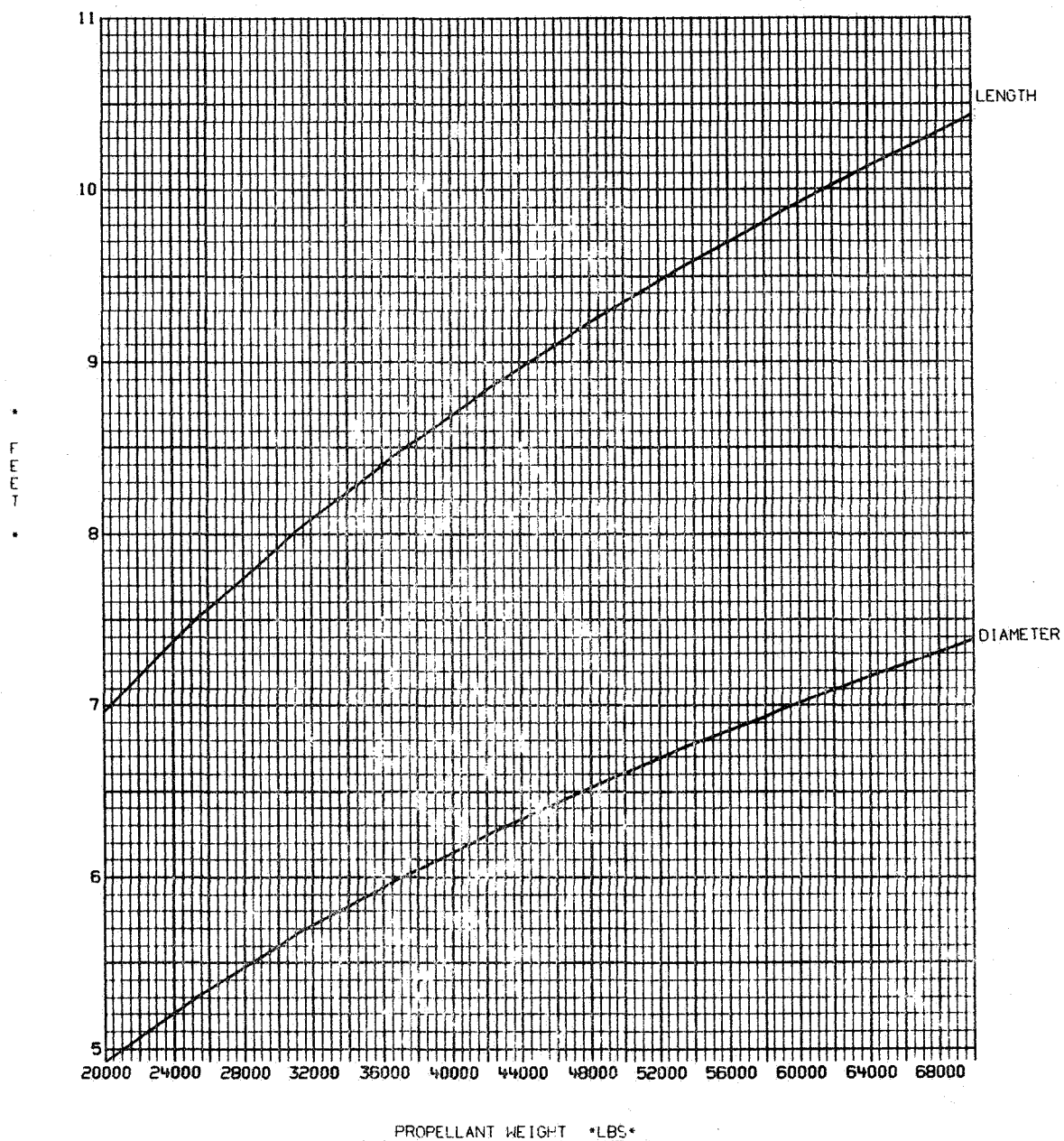


Figure 2-71

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

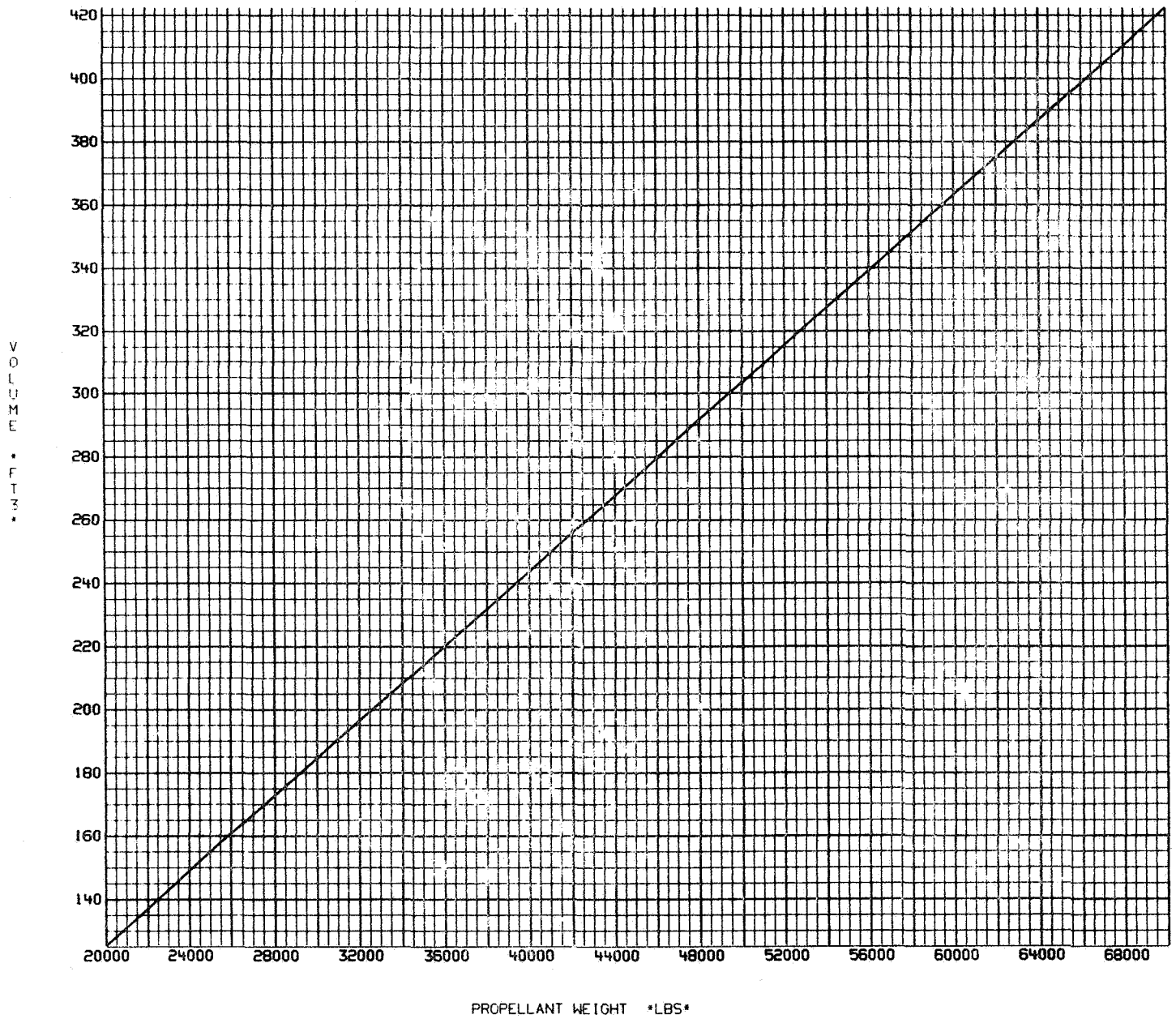


Figure 2-72

FUEL TANK

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

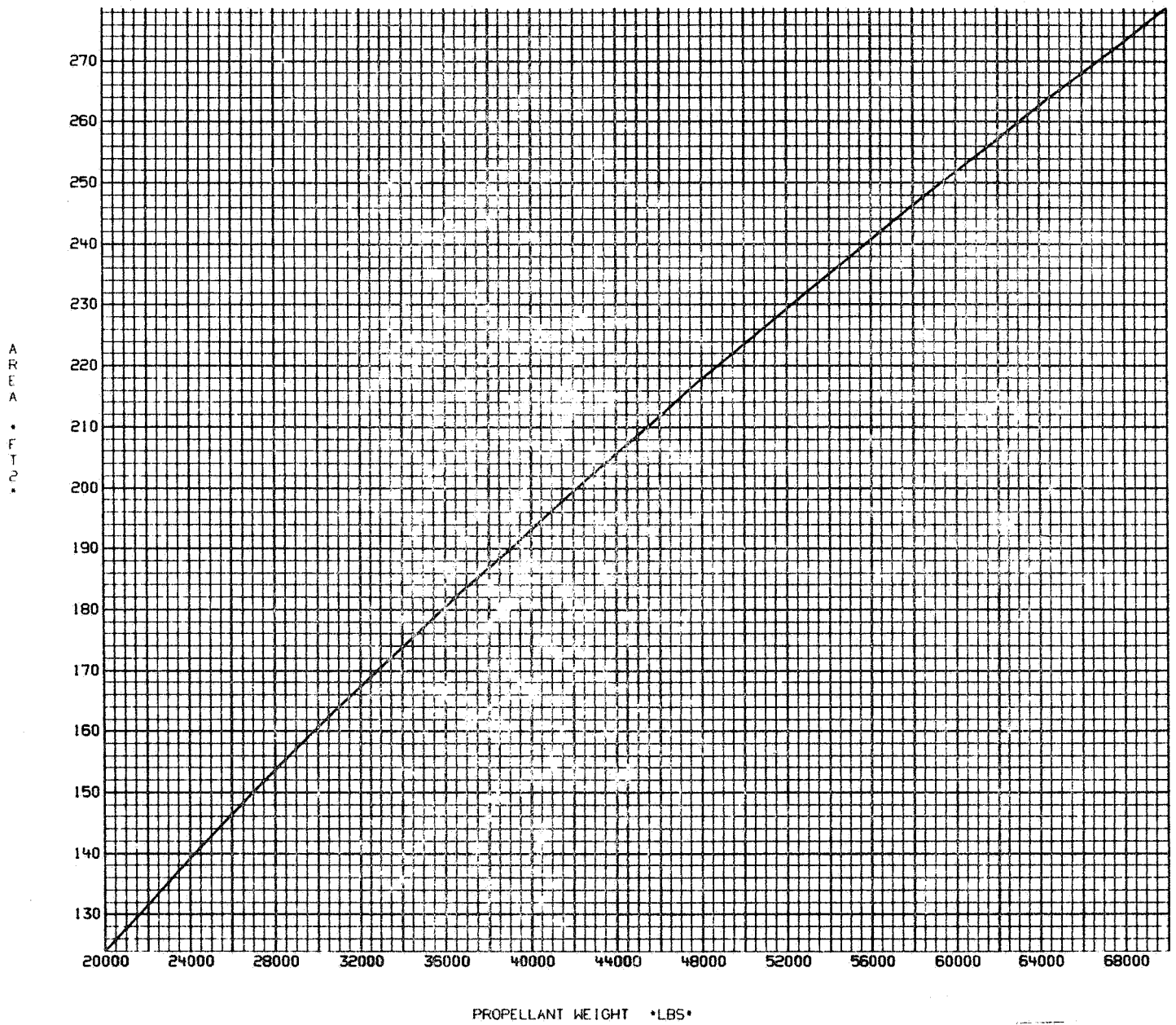


Figure 2-73

AREA OF CYLINDER + CONE

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

419.0 SEC. SPECIFIC IMPULSE

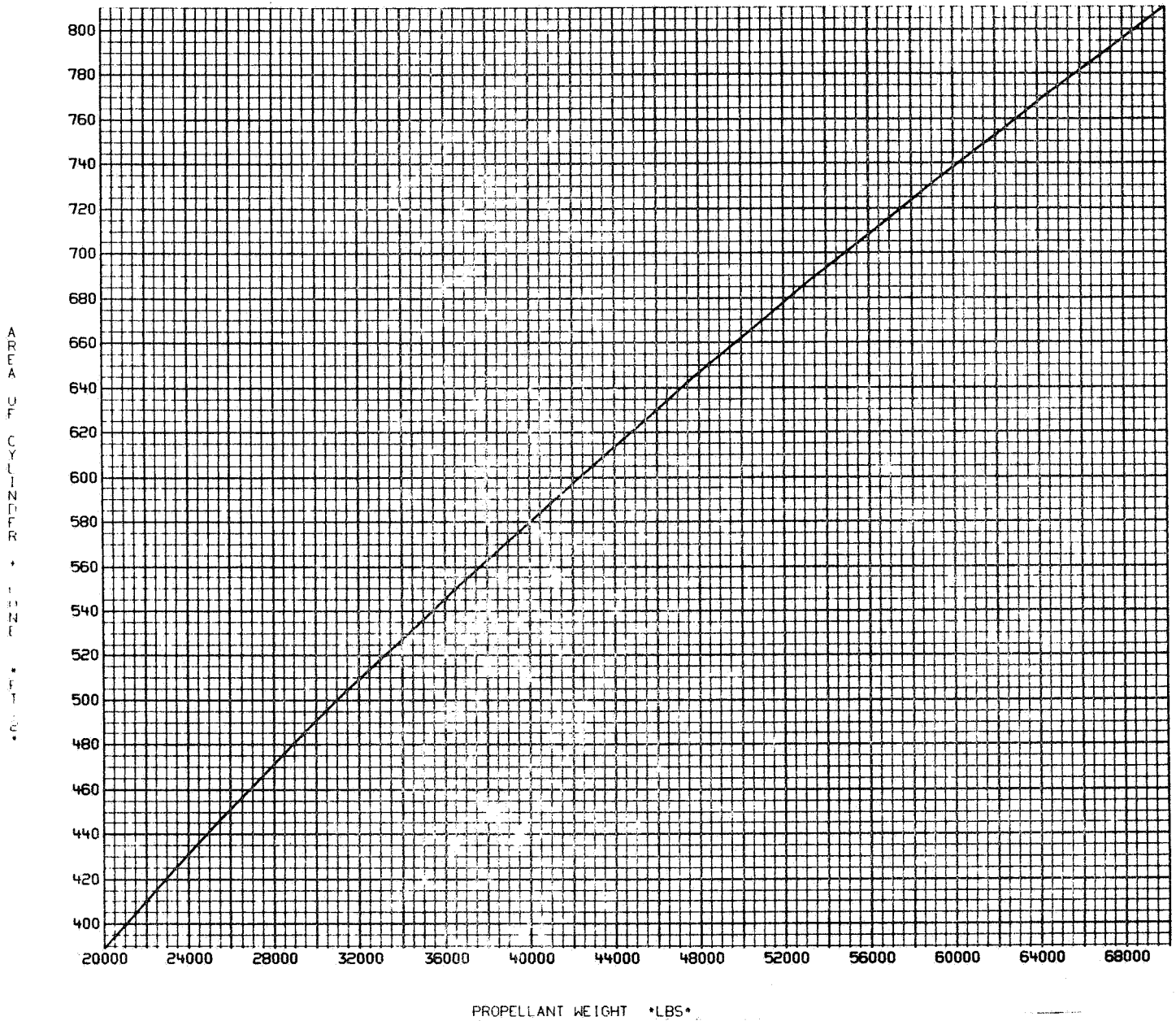


Figure 2-74

STAGE LENGTH

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

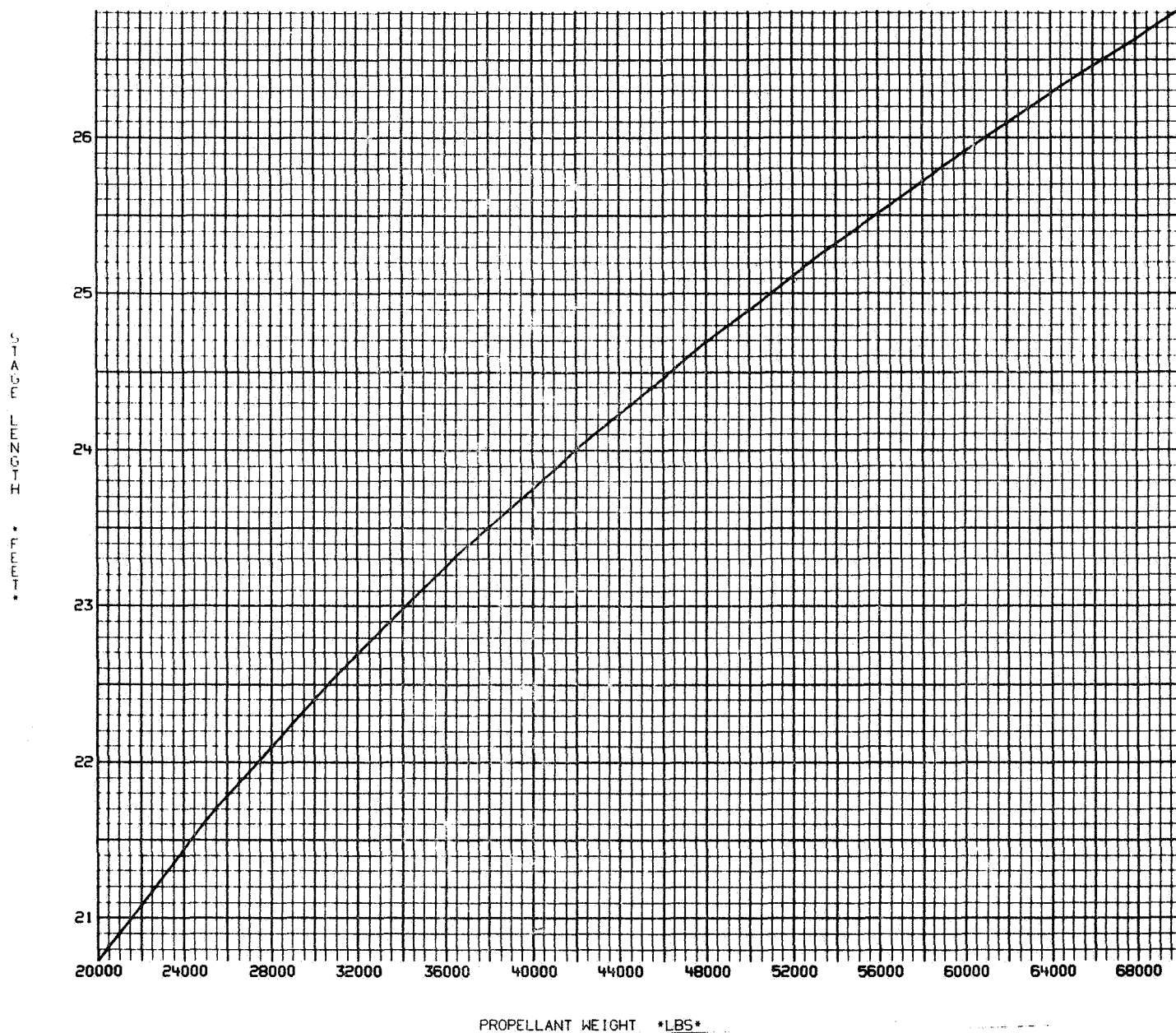


Figure 2-75

STRUCTURE

EXPENDABLE MODE

FLOX METHANE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

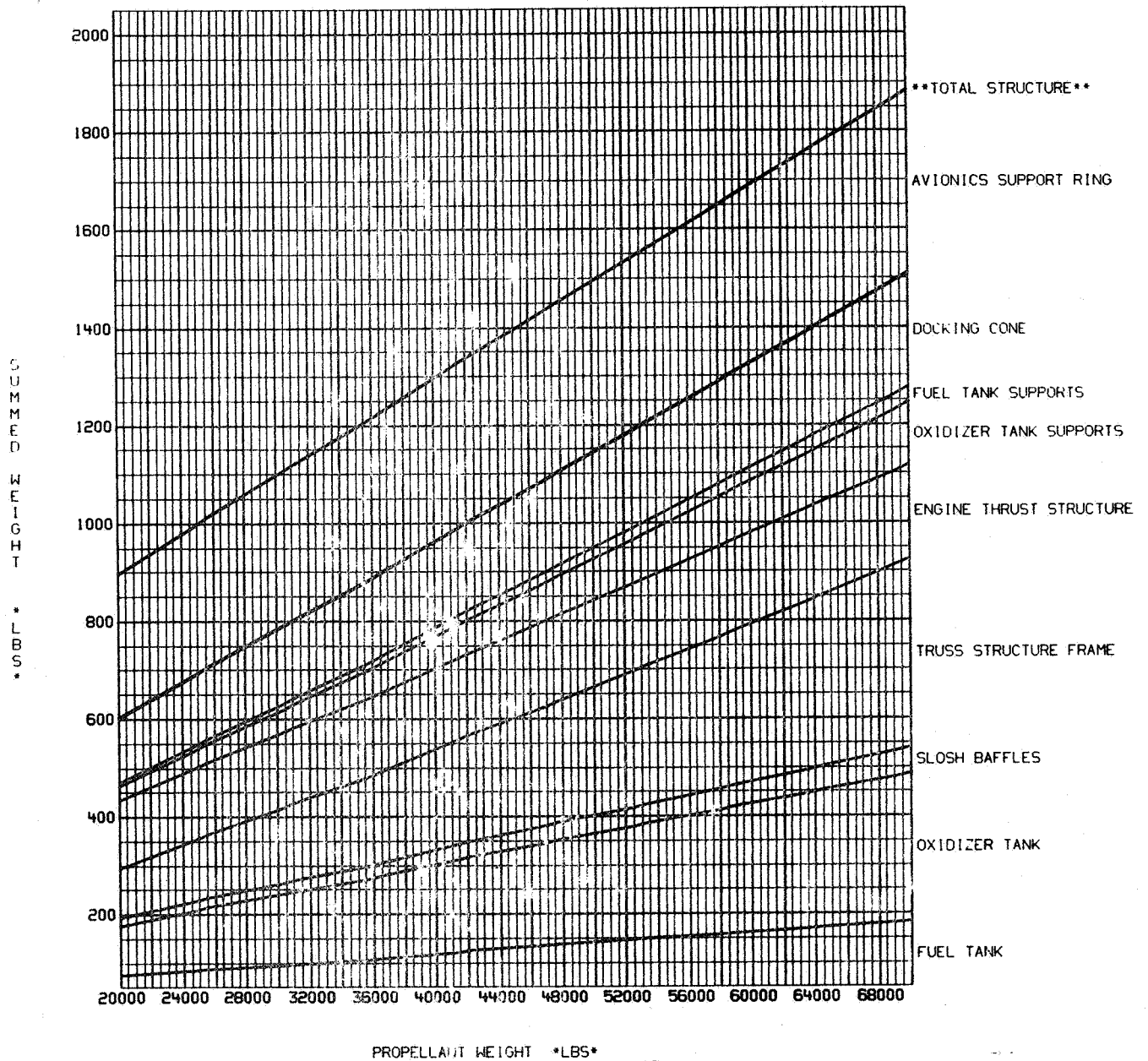


Figure 2-76

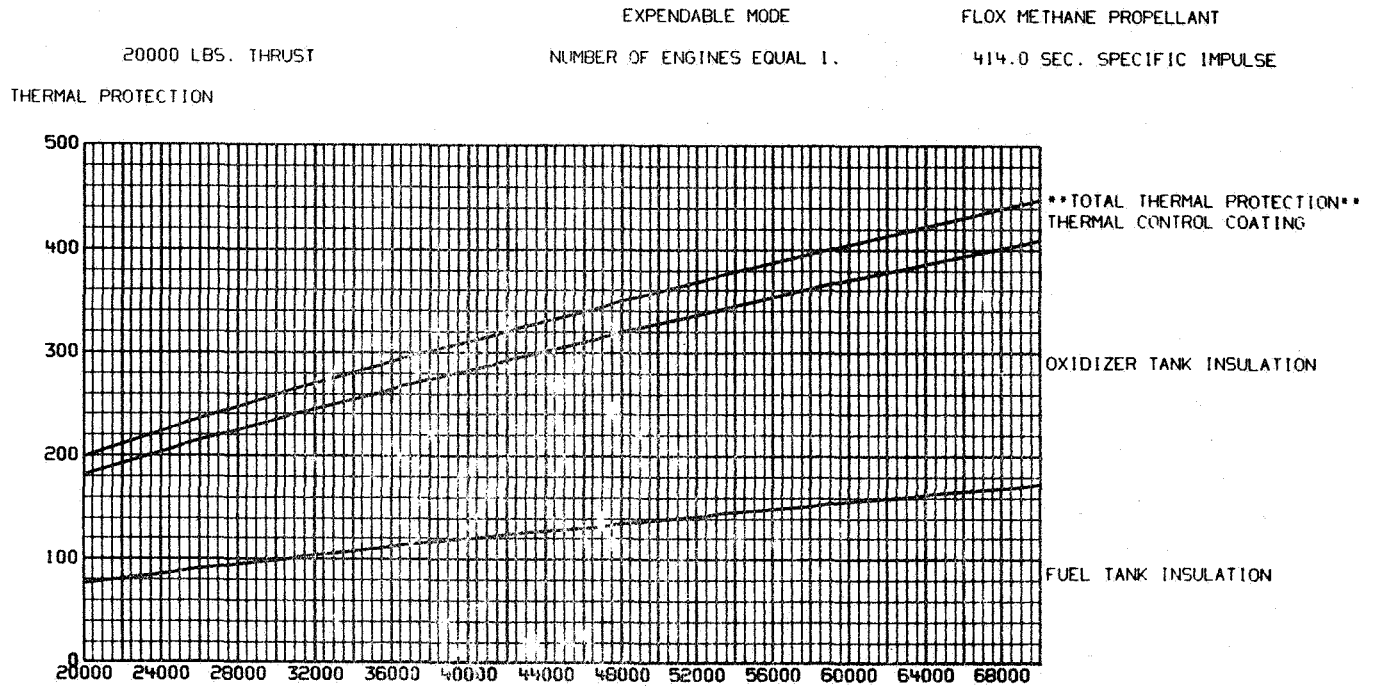


Figure 2-77

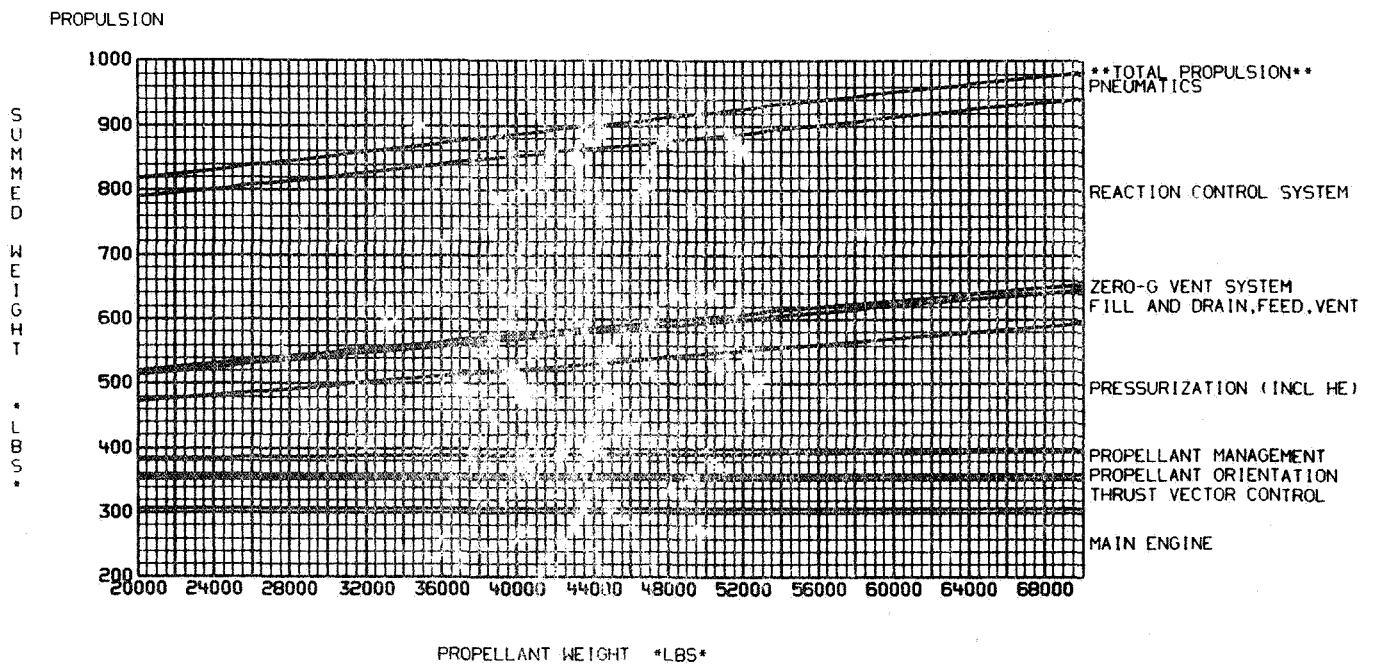


Figure 2-69

AVIONICS AND ELECTRICAL POWER
20000 LBS. THRUST

EXPENDABLE MODE
NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT
414.0 SEC. SPECIFIC IMPULSE

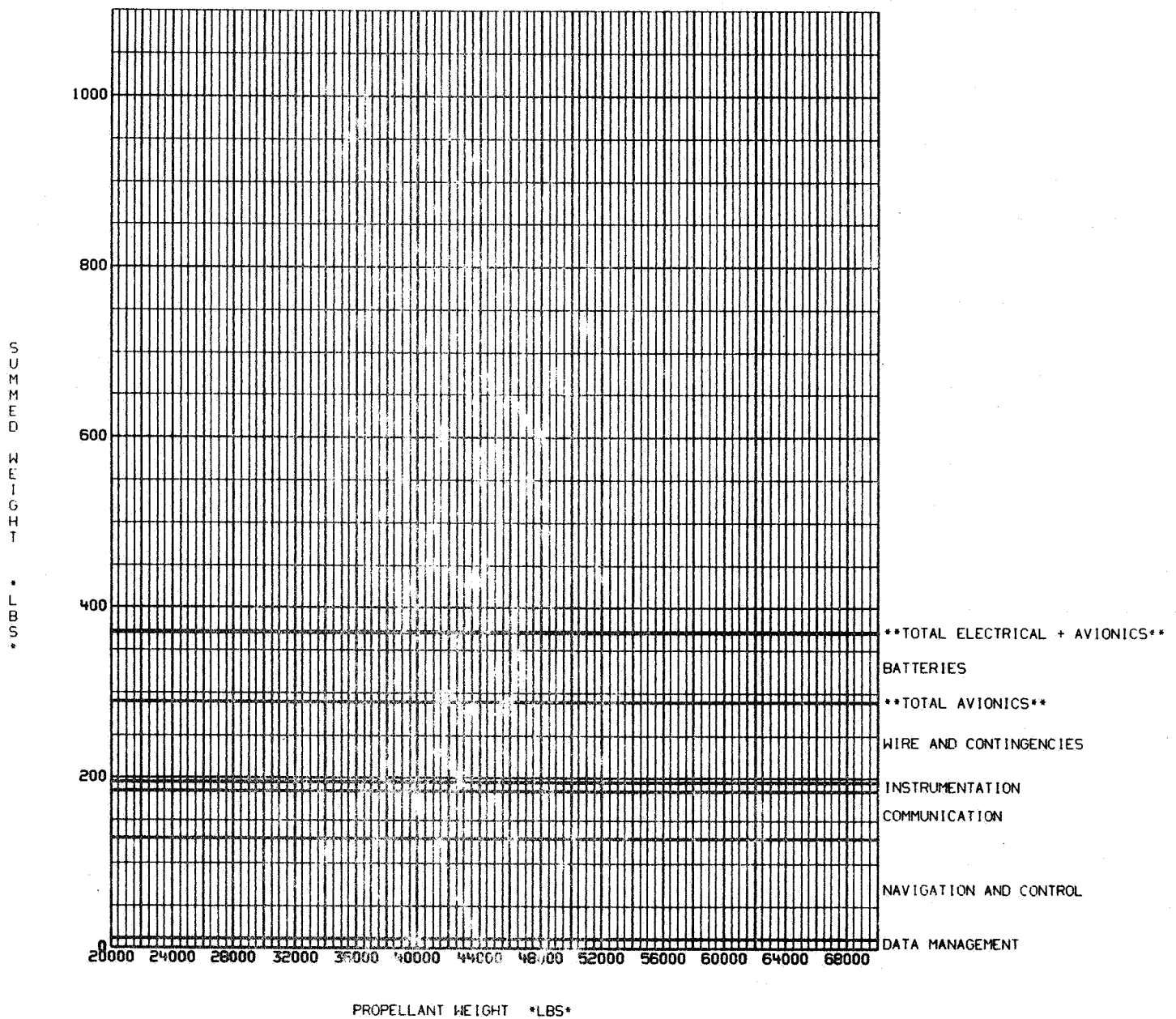


Figure 2-79

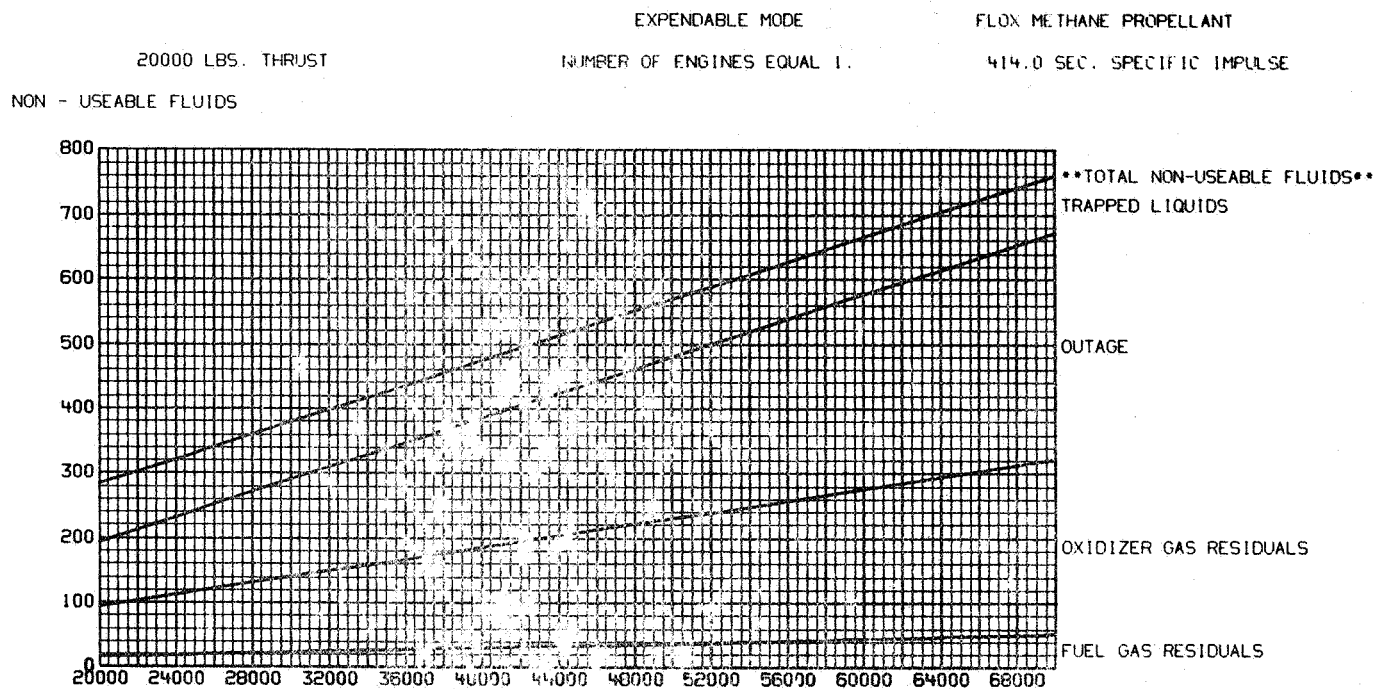


Figure 2-80

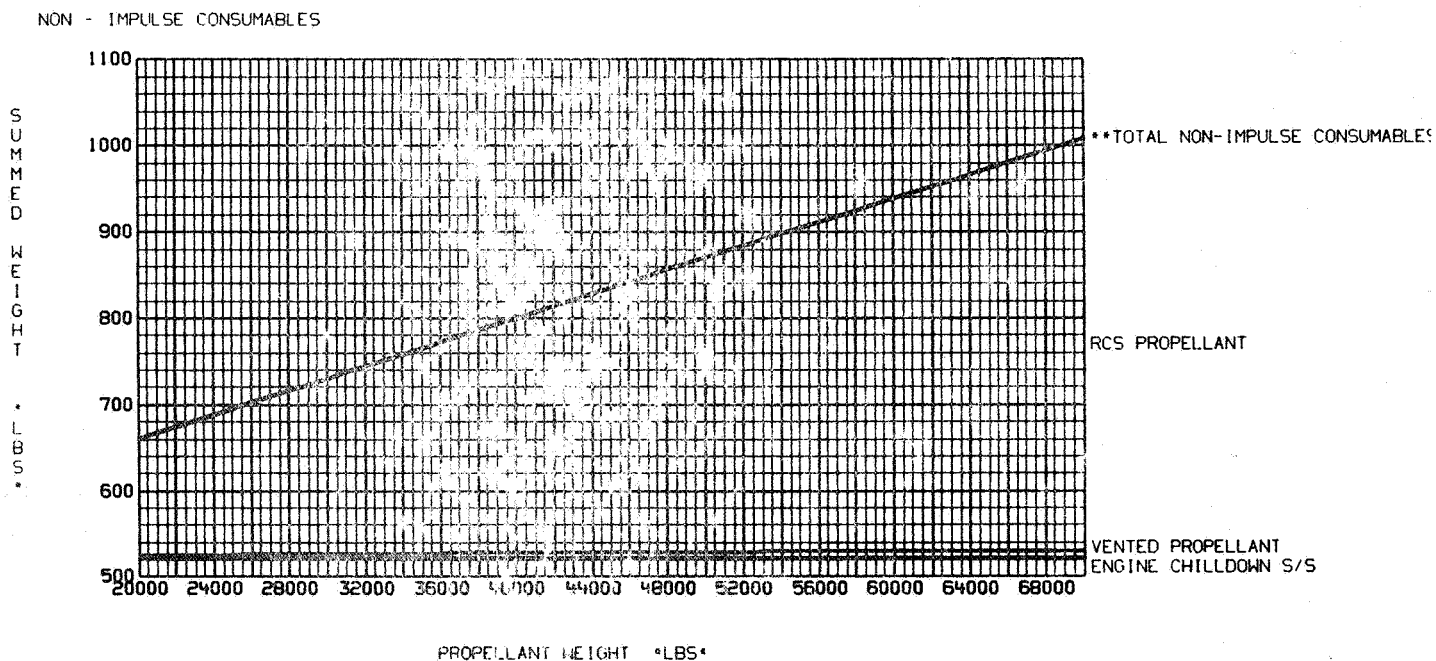


Figure 2-81

ADVANCED TUG SYSTEM WEIGHTS

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

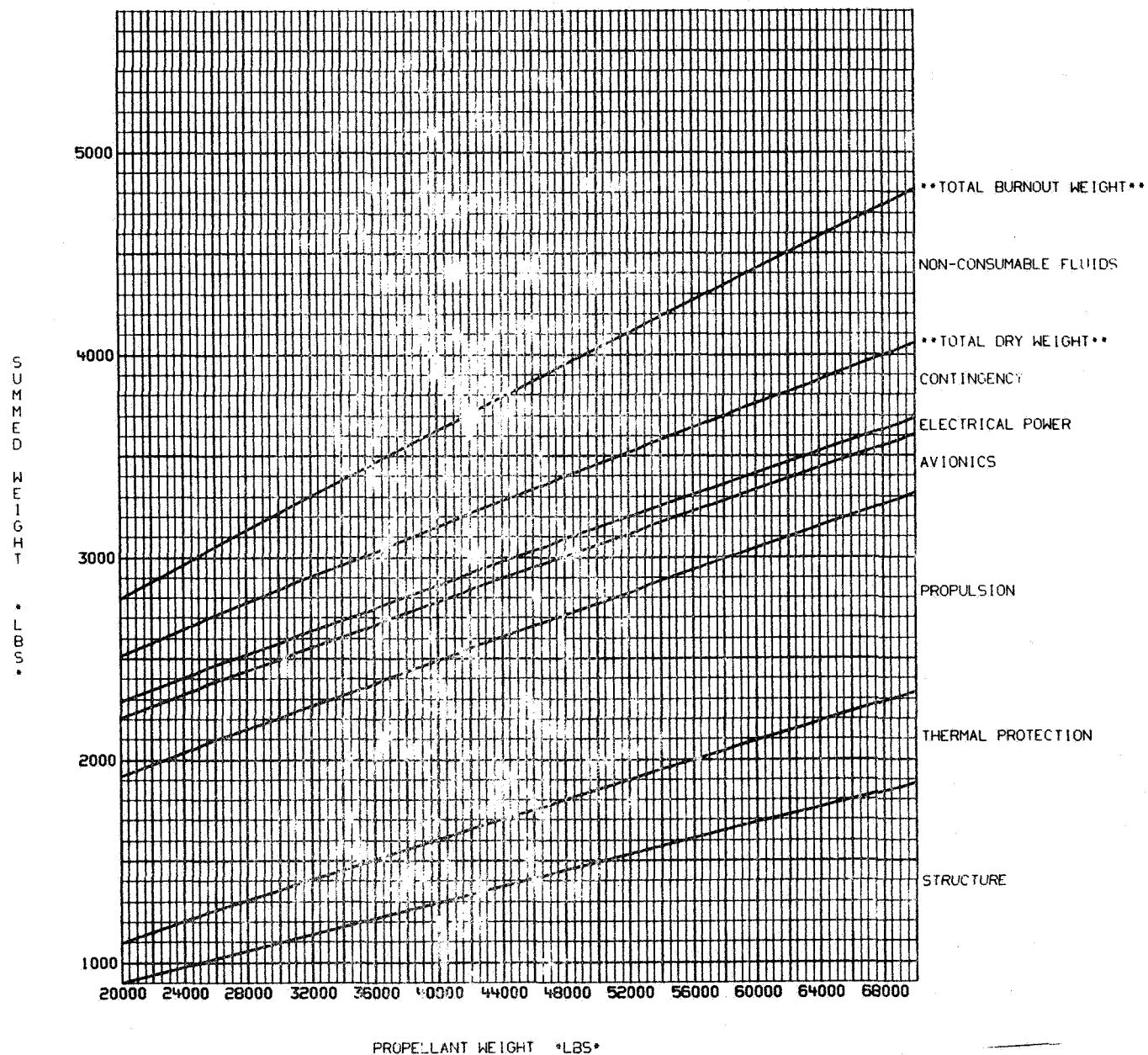


Figure 2-82

BURNOUT AND TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

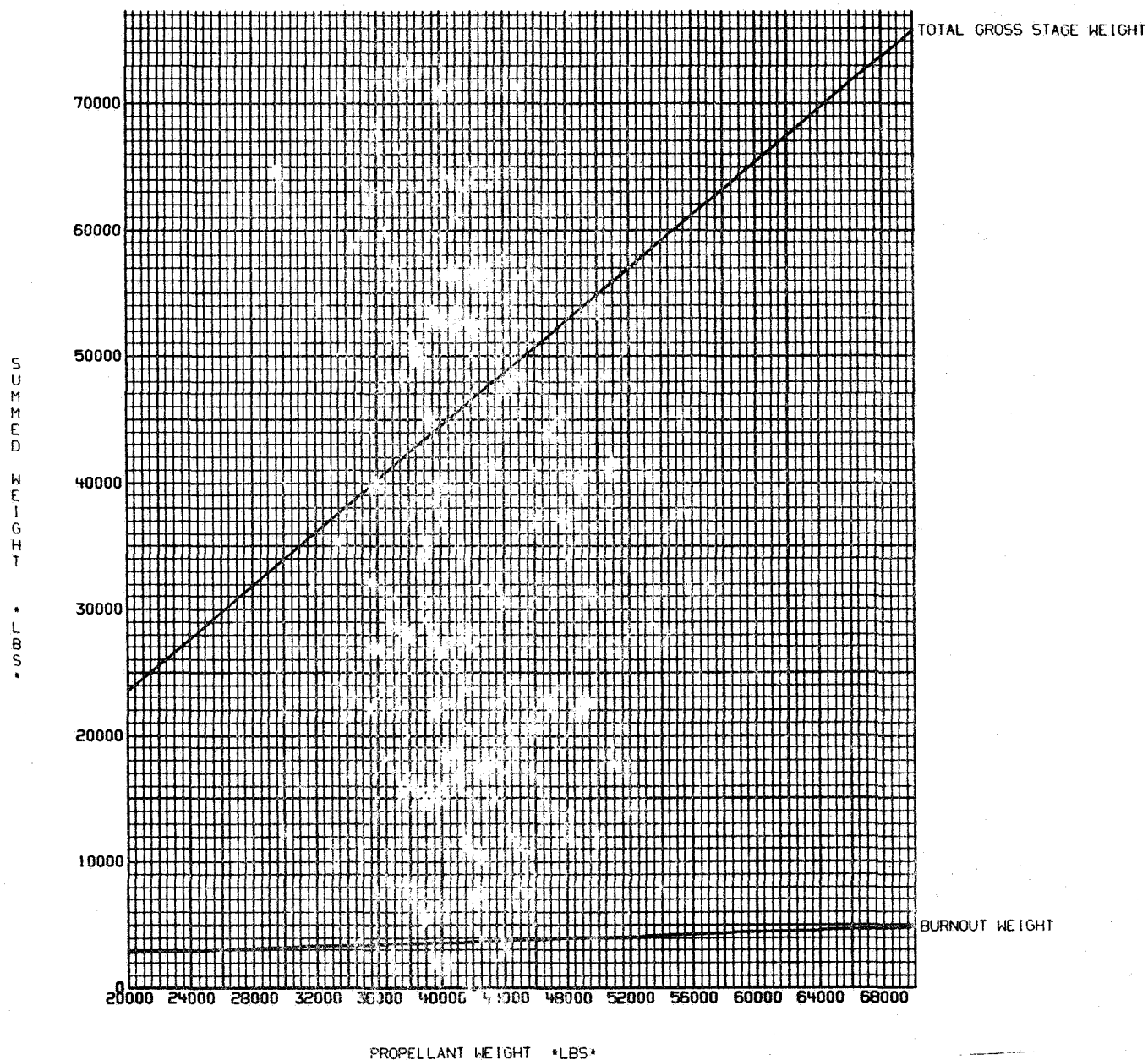


Figure 2-83

LAMBDA PRIME BASED ON TOTAL GROSS STAGE WEIGHT

20000 LBS. THRUST

EXPENDABLE MODE

NUMBER OF ENGINES EQUAL 1.

FLOX METHANE PROPELLANT

414.0 SEC. SPECIFIC IMPULSE

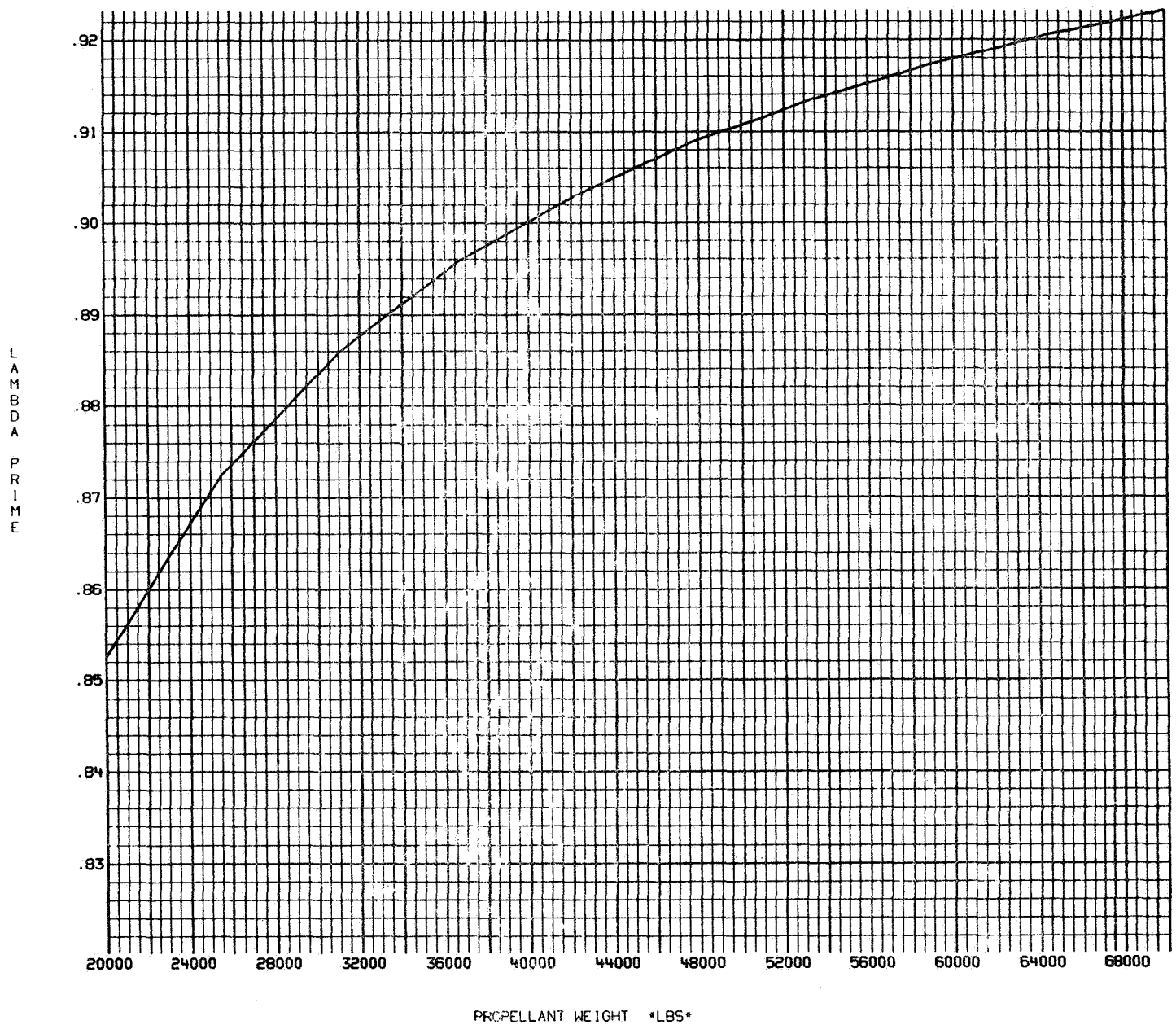


Figure 2-84

LAMBDA PRIME BASED ON BURNOUT WEIGHT AND IMPULSE PROP.

EXPENDABLE MODE

FLOX METHANE PROPELLANT

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

414.0 SEC. SPECIFIC IMPULSE

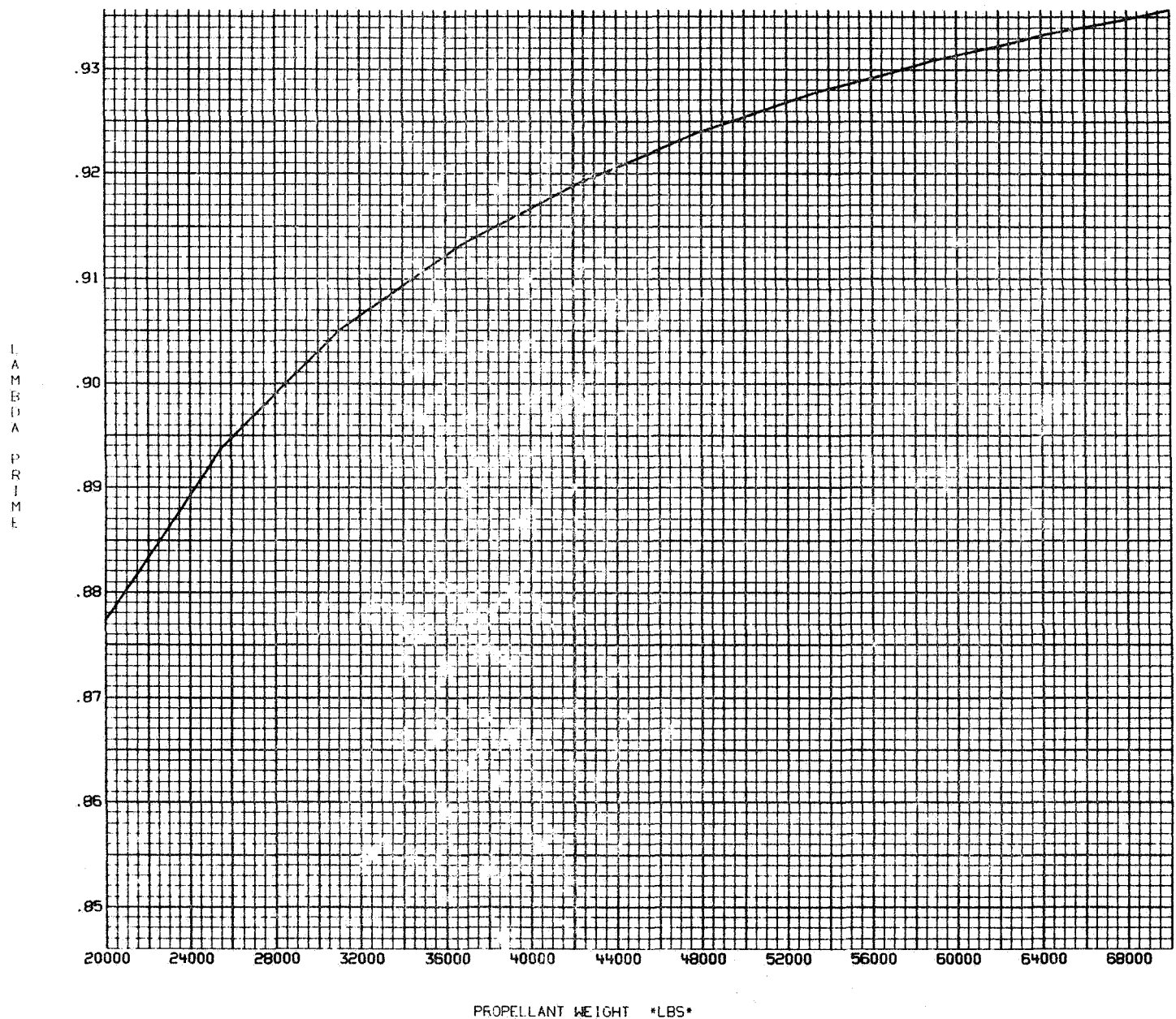


Figure 2-85

DROP TANK STRUCTURE

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460 SEC. SPECIFIC IMPULSE

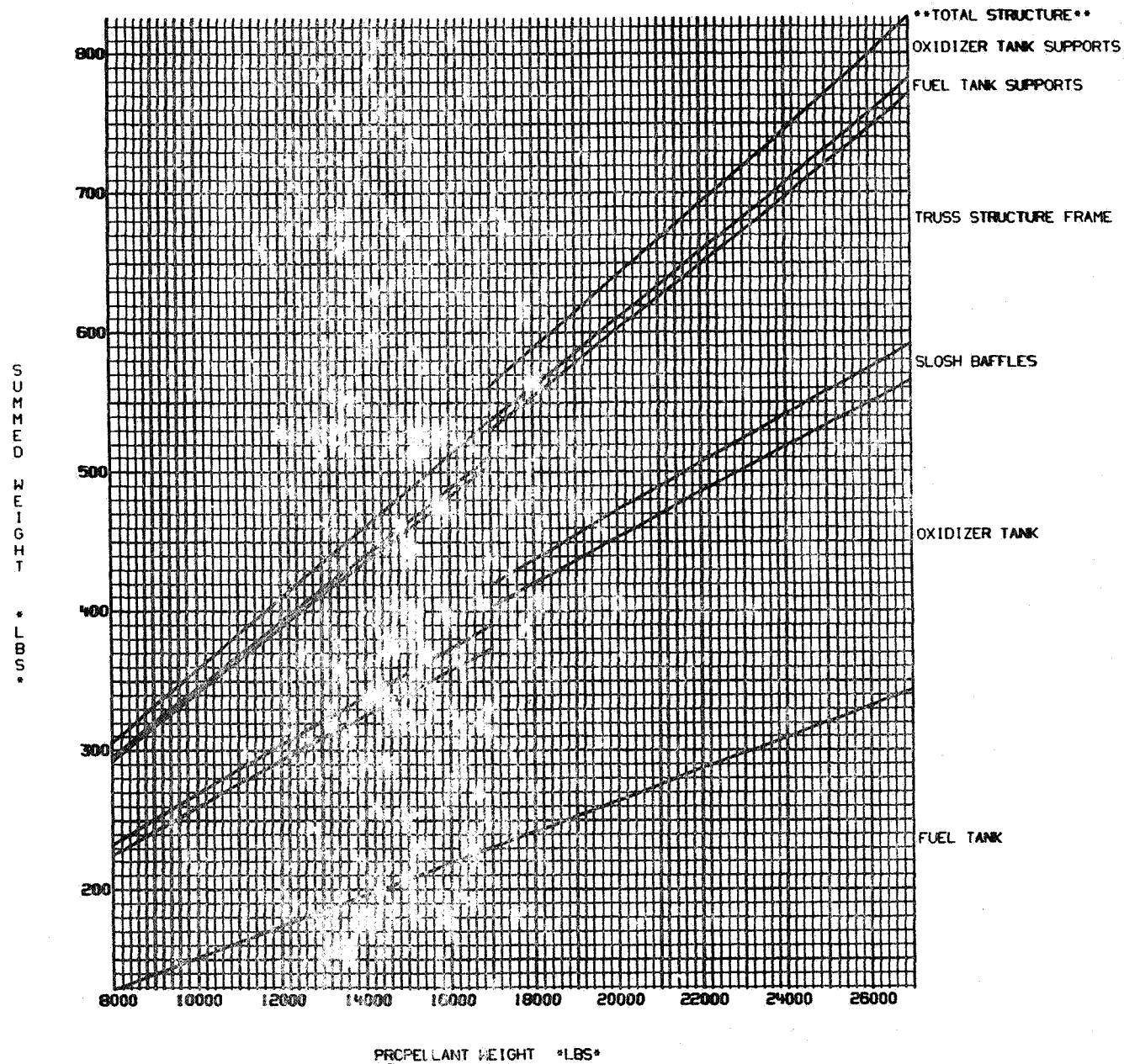


Figure 2-86

LOX HYDROGEN PROPELLANT

460 SEC. SPECIFIC IMPULSE

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

DROP TANK THERMAL PROTECTION

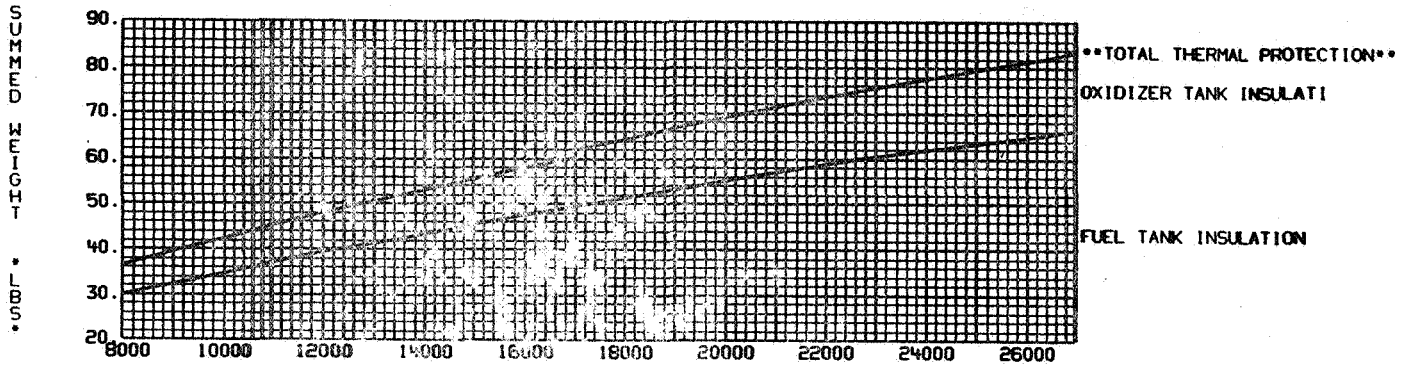


Figure 2-87

DROP TANK PROPULSION

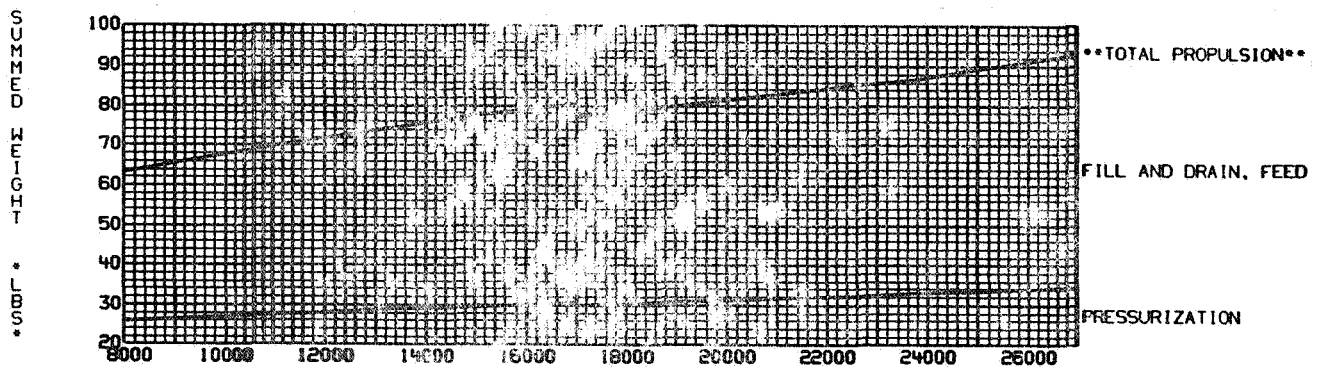


Figure 2-88

DROP TANK NON-CONSUMABLES

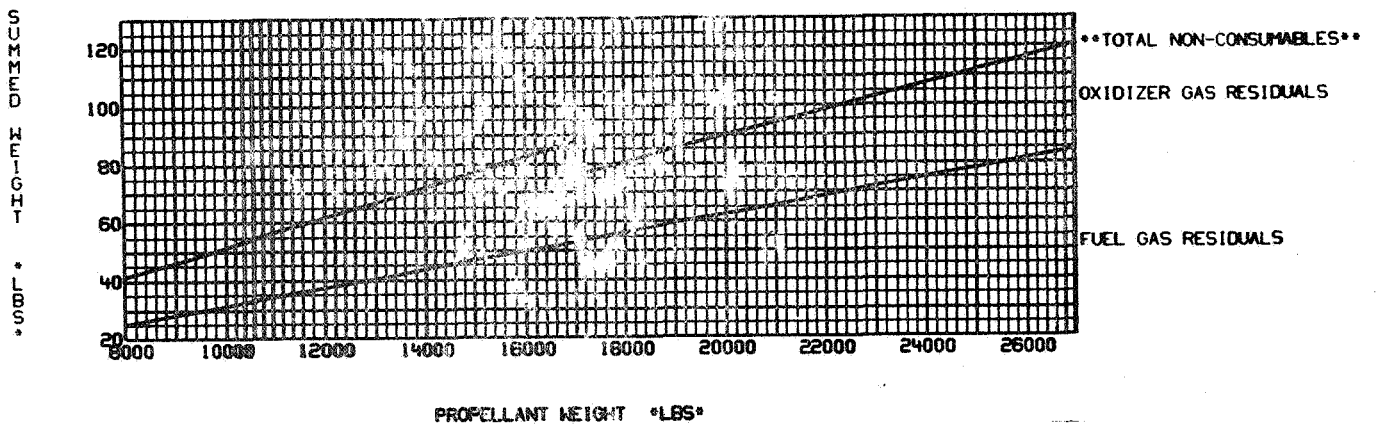


Figure 2-89

DROP TANK TOTAL SUBSYSTEMS

20000 LBS. THRUST

NUMBER OF ENGINES EQUAL 1.

LOX HYDROGEN PROPELLANT

460 SEC. SPECIFIC IMPULSE

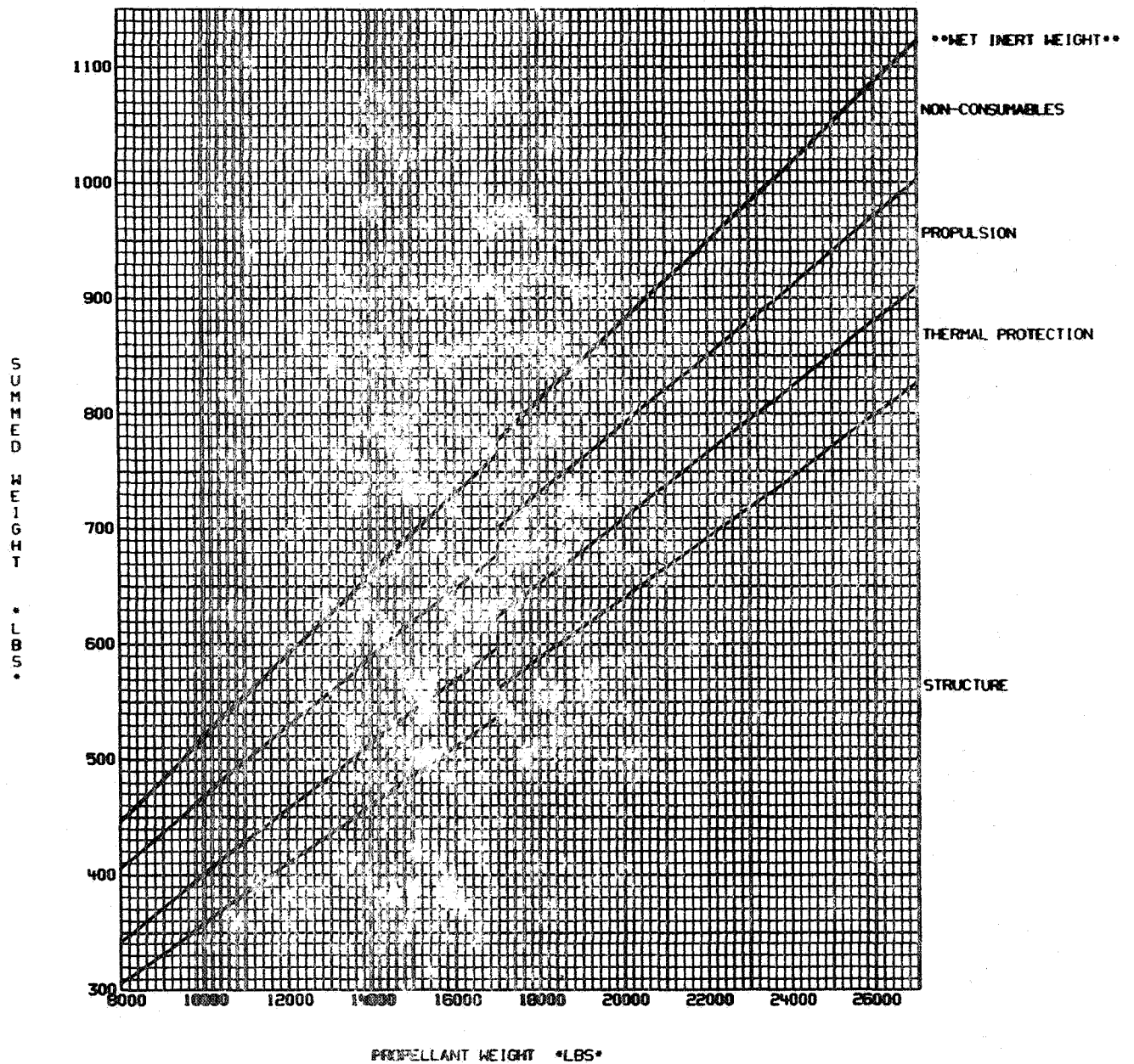


Figure 2-90

Chapter 3

PERFORMANCE DATA

This chapter presents detailed data on the performance characteristics and sensitivities associated with expendable orbit injection stages and reusable Space Tugs analyzed during the Space Tug Economic Analysis Study. The Tug concepts for which performance data are presented in this chapter are all point designs of primary interest in the study, namely the four candidate orbit injection stages (Agena, Large Tank Agena, D-1T Centaur, and Growth Tank Centaur), and single-stage ground-based reusable Tugs with LO_2/LH_2 , LF_2/LH_2 and FLOX/CH_4 propellants. The reusable Tugs are generally sized to about 50,000 lb propellant loading, except that a smaller (36,300 lb) LO_2/LH_2 concept is included to show the performance variation with decreased stage size.

The performance data were generated automatically within the STAR computer program and directly plotted by the computer. The equations and methodology used to derive the performance data are presented in Part 1 of Volume II.

To assist the reader in locating any particular performance data in Chapter 3, a roadmap matrix of Tug concepts and performance data has been formatted; this matrix references specific figure numbers in the pages following. The matrix is presented as Table 3-1. Flight modes referenced for the reusable Tugs are as follows:

- Mode 1 – Delivery of a payload on the outbound leg of a roundtrip Tug flight and return with a payload of equal weight on the inbound leg
- Mode 2 – Retrieval, only, of a payload on a roundtrip Tug flight
- Mode 3 – Delivery, only, of a payload on a roundtrip Tug flight
- Mode 4 – Delivery of a payload on a one-way Tug flight

All of the orbit injection stages are flown in Mode 4.

Table 3-1. ROADMAP OF TUG PERFORMANCE DATA IN CHAPTER 3
(All References are to Figure Numbers)

	Orbit Injection Stages			Reusable LO ₂ /LH ₂ Tug (W _p = 50.2K)			Reusable LO ₂ /LH ₂ Tug (W _p = 36.3K)			Reusable LF ₂ /LH ₂ Tug (W _p = 47.8K)			Reusable FLOX/CH ₄ Tug (W _p = 52.0K)		
	Agna	LT	D-1T	GT	Mode 1	Mode 2	Mode 3	Mode 4	Mode 1	Mode 2	Mode 3	Mode 4	Mode 1	Mode 2	Mode 3
Payload Capability vs On-Orbit Velocity	3-1	3-8	3-15	3-22	3-29	3-38	3-45	3-52	3-59	3-68	3-75	3-82	3-119	3-125	3-135
Partial Derivative of Payload Capability with Respect to Tug \dot{V}_{sp}	3-2	3-9	3-16	3-23	3-30	3-39	3-46	3-52	3-60	3-69	3-76	3-83	3-120	3-129	3-136
Partial Derivative of Payload Capability with Respect to Tug Inert Weight	3-3	3-10	3-17	3-24	3-31	3-40	3-47	3-54	3-61	3-70	3-77	3-84	3-121	3-130	3-137
Partial Derivative of Payload Capability with Respect to Outbound Velocity	3-4	3-11	3-18	3-25	3-32	N/A	3-45	3-55	3-62	N/A	3-76	3-85	3-122	N/A	3-138
Partial Derivative of Payload Capability with Respect to Inbound Velocity	N/A	N/A	N/A	N/A	3-33	3-41	N/A	N/A	3-63	3-71	N/A	N/A	3-123	3-131	N/A
Partial Derivative of Payload Capability with Respect to Tug Propellant Weight	3-5	3-12	3-19	3-26	3-34	3-42	3-49	3-56	3-64	3-72	3-79	3-86	3-124	3-132	3-139
Partial Derivative of Payload Capability with Respect to Tug Ignition Weight	3-6	3-13	3-20	3-27	3-35	3-43	3-50	3-57	3-65	3-73	3-80	3-87	3-125	3-133	3-140
Partial Derivative of Payload Capability with Respect to Ratio of Outbound to Total Payload	N/A	N/A	N/A	N/A	3-36	N/A	N/A	N/A	3-66	N/A	N/A	N/A	3-126	N/A	N/A
Propellant Offloading vs On-Orbit Velocity	3-7	3-14	3-21	3-28	3-37	3-44	3-51	3-58	3-67	3-74	3-81	3-88	3-127	3-134	3-141

STANDARD
AGENA

PAYLOAD DELIVERED		13386 LBS. FIXED PROPELLANT WEIGHT	EXPENDABLE TUG AND P/L
• = FIXED PROPELLANT 13386 LBS.	O = FIXED IGNITION 30000 LBS.		■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.		

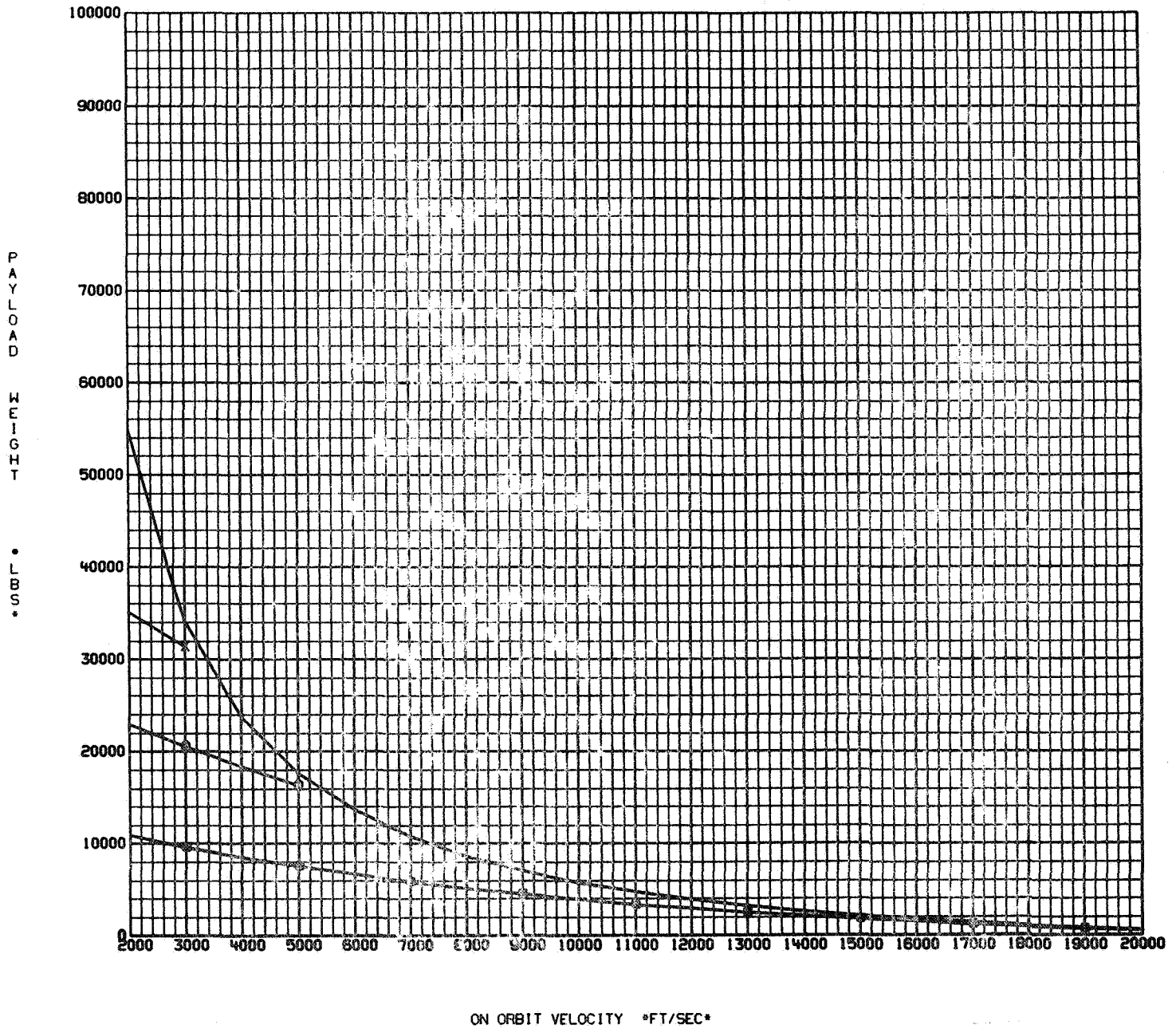


Figure 3-1

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT

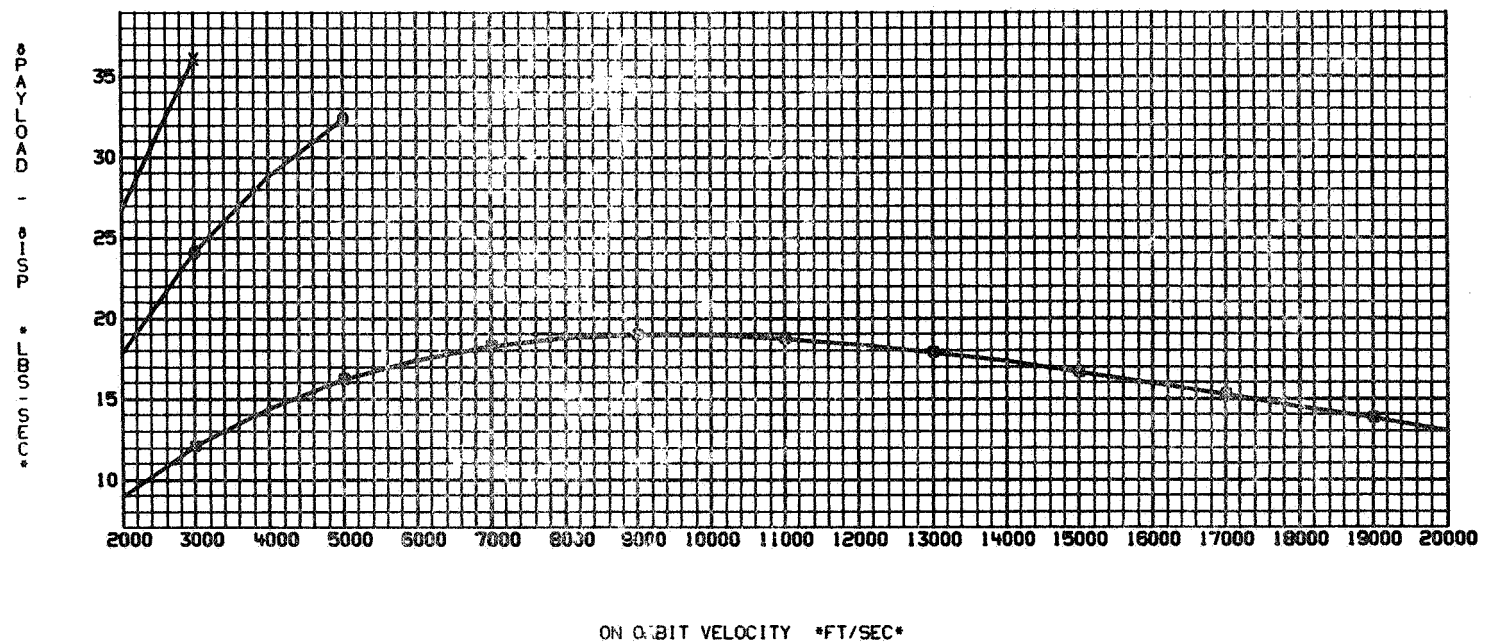
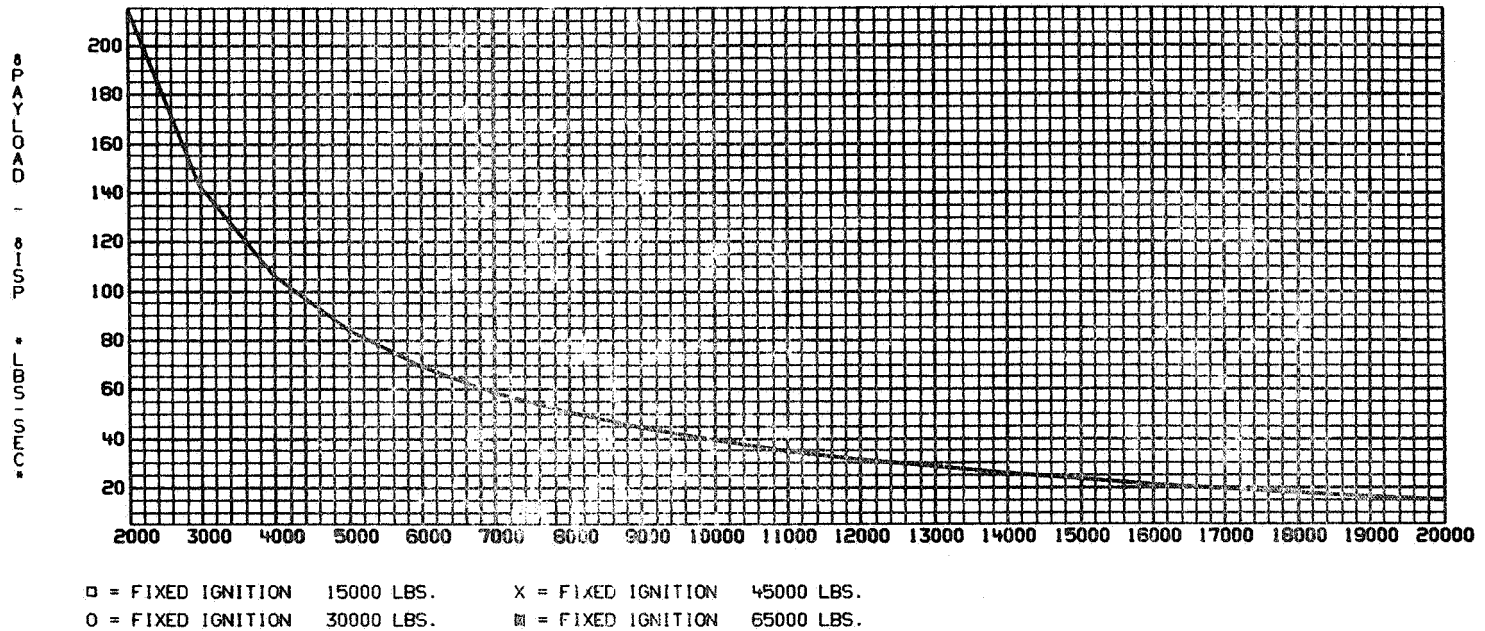
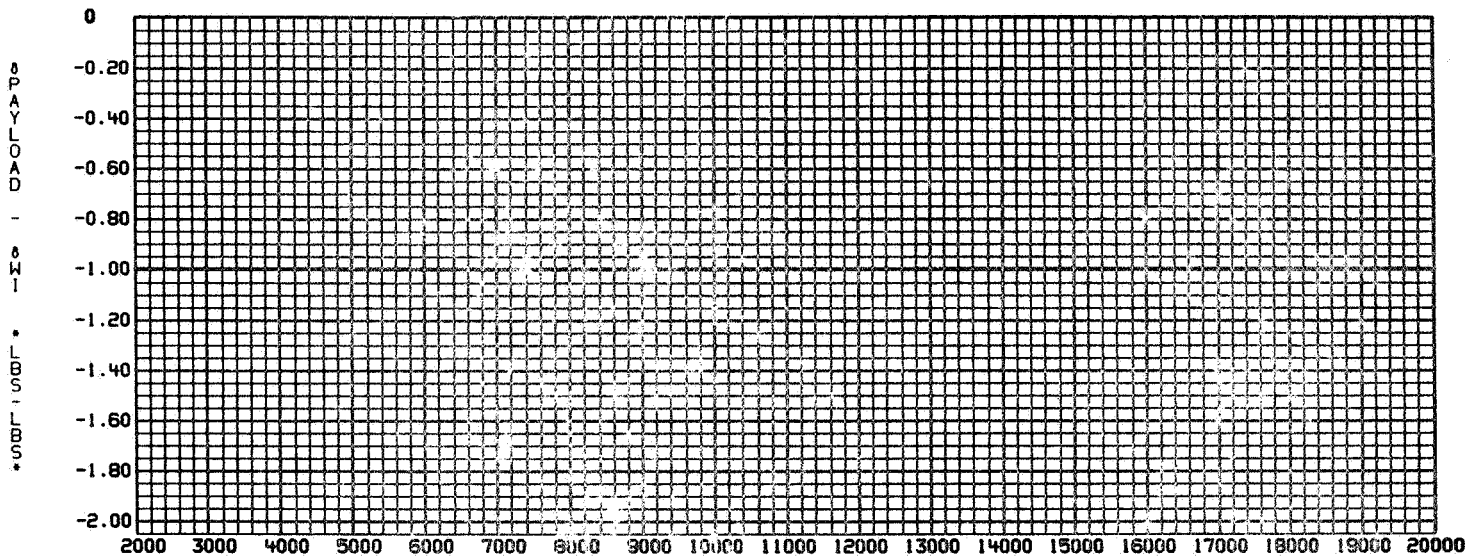


Figure 3-2

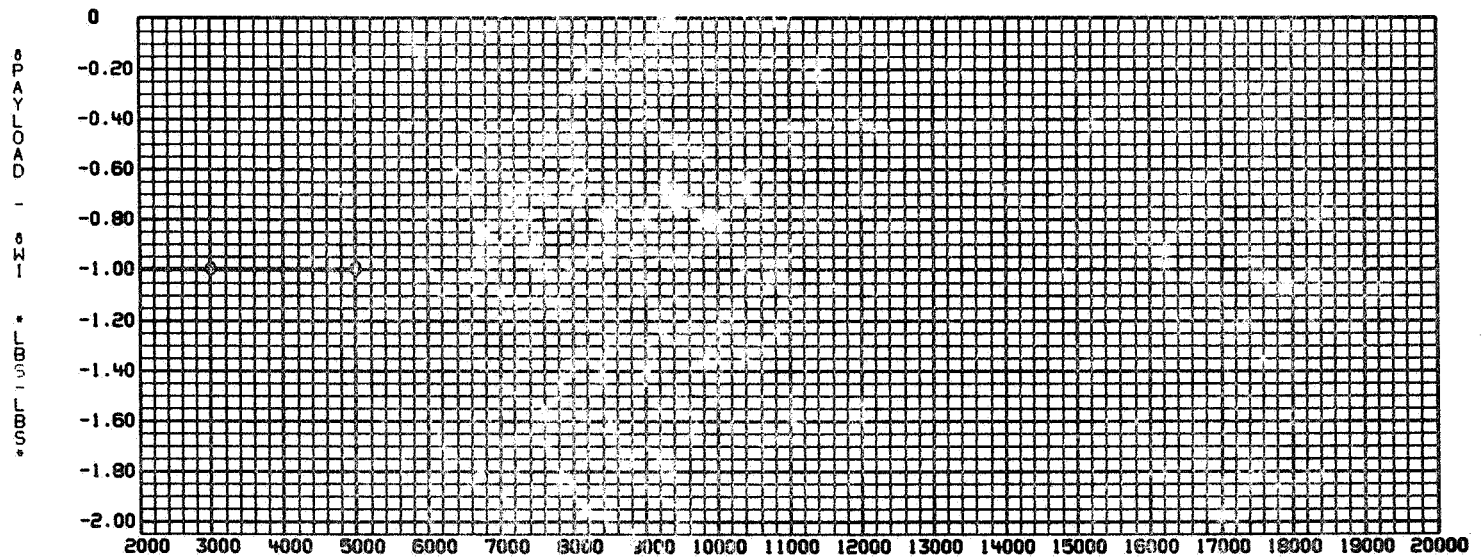
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



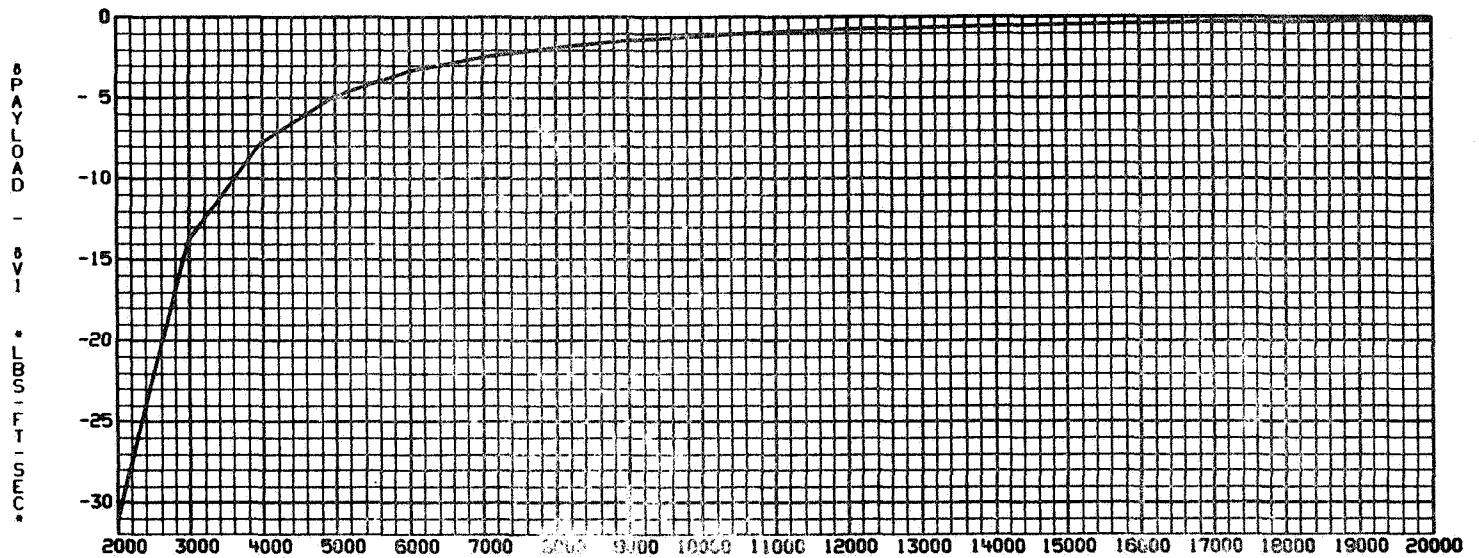
ON ORBIT VELOCITY *FT/SEC*

Figure 3-3

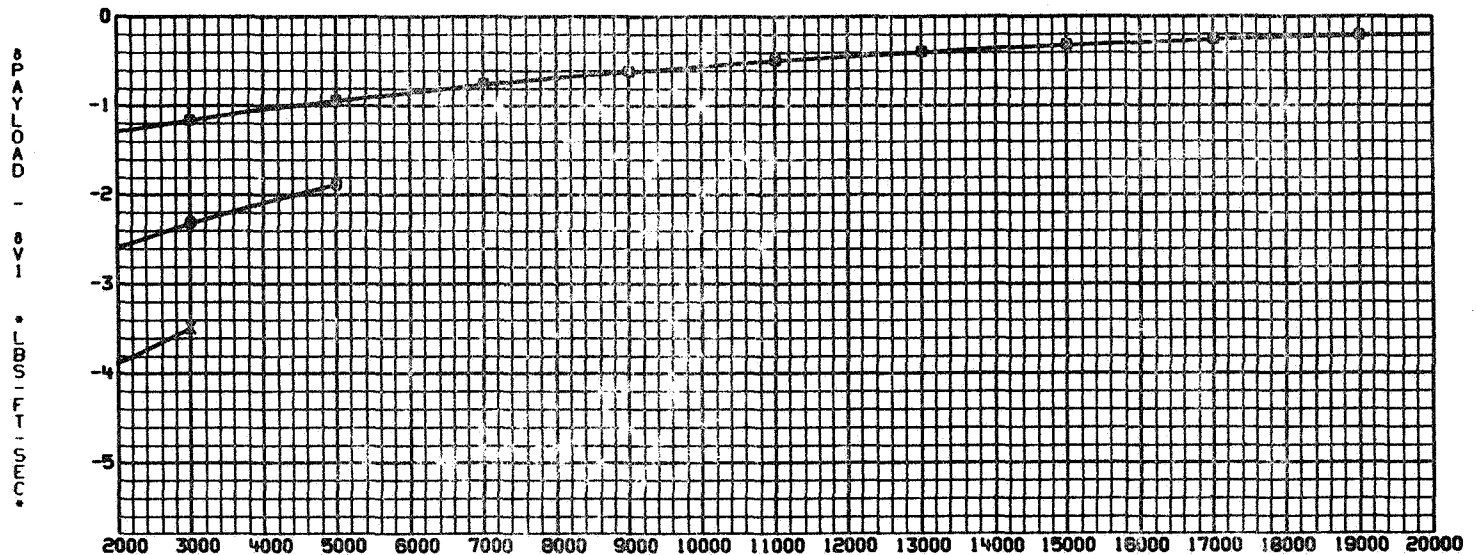
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-4

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

13386 LBS. FIXED PROPELLANT WEIGHT

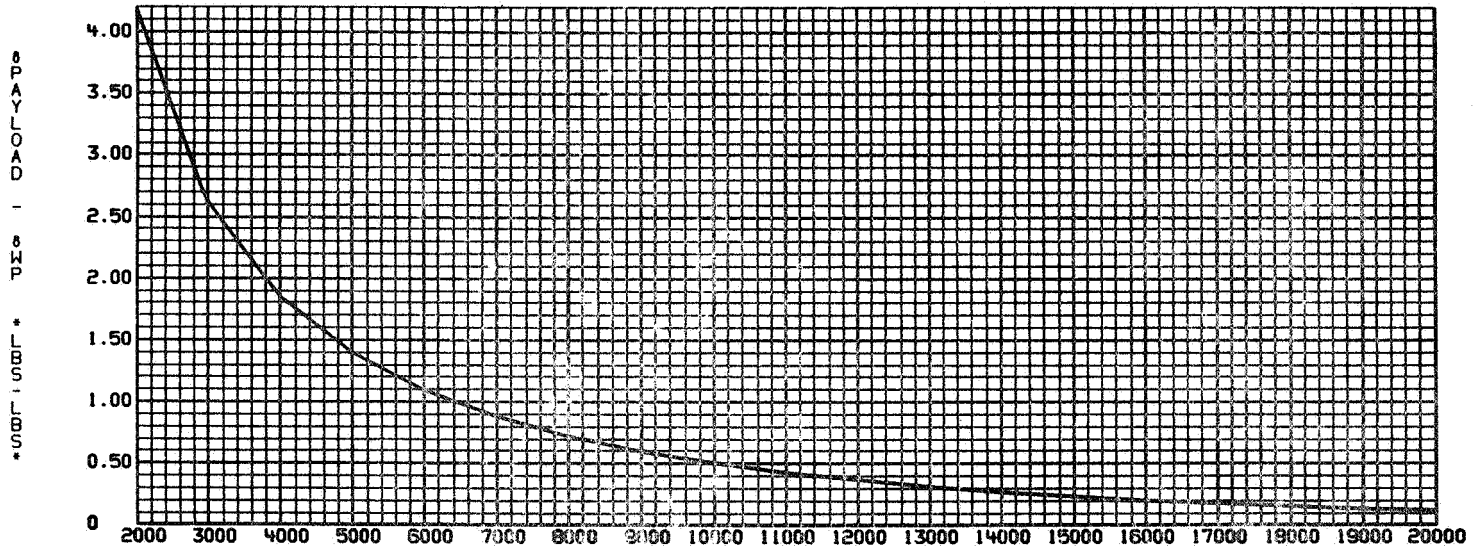
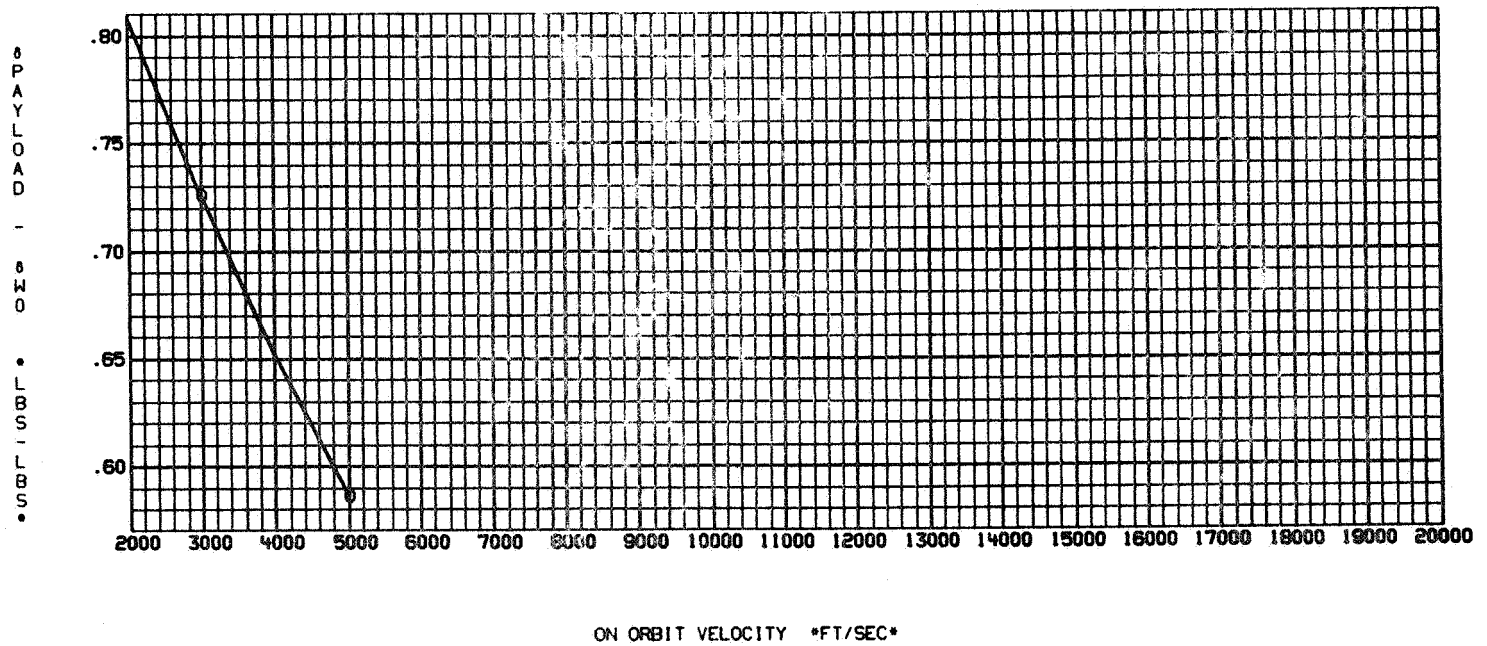


Figure 3-5

ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-6

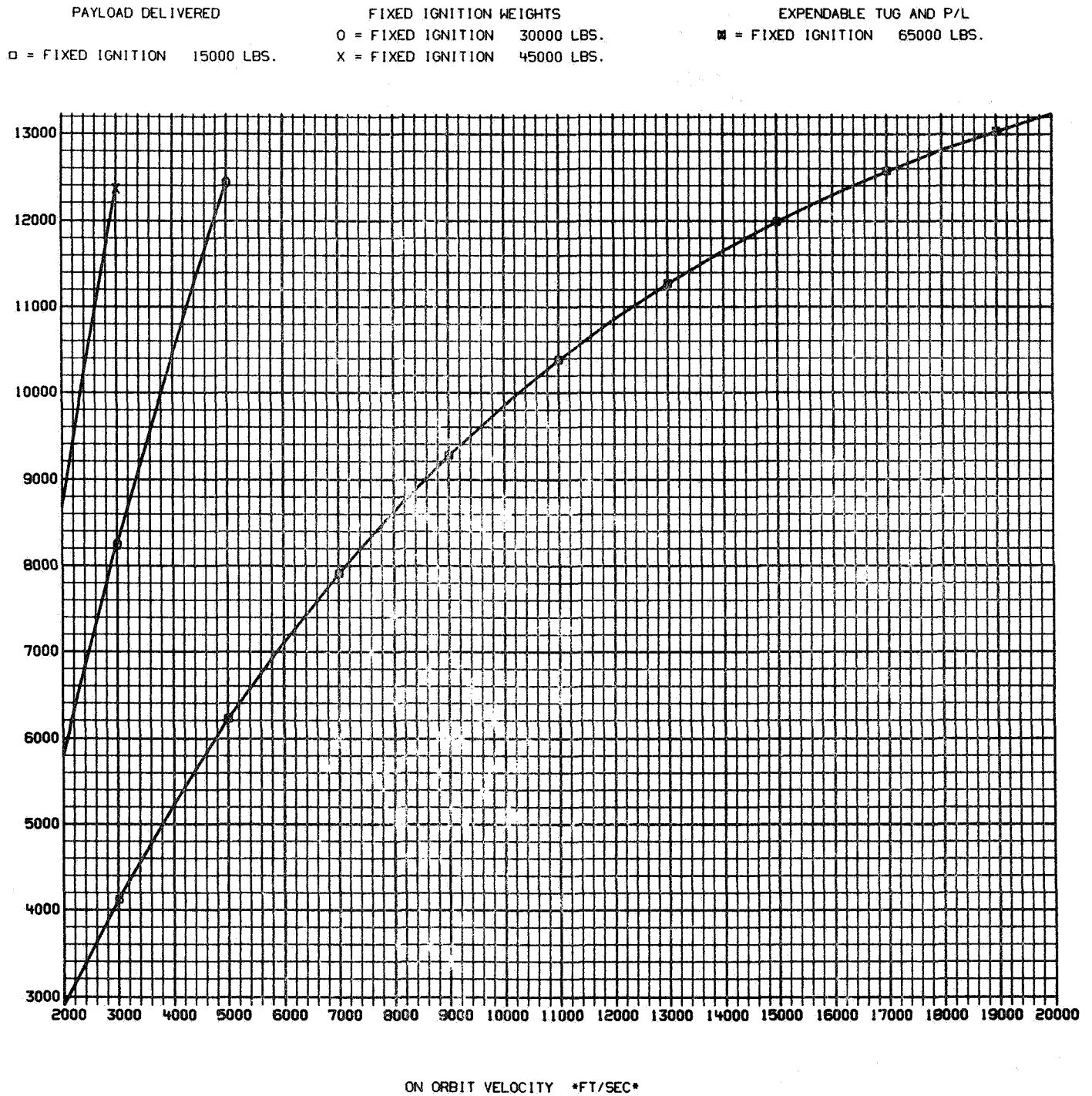


Figure 3-7

LARGE TANK AGENA

$W_p = 50,730 \text{ LB}$

PAYLOAD DELIVERED		50730 LBS. FIXED PROPELLANT WEIGHT		EXPENDABLE TUG AND P/L	
•	= FIXED PROPELLANT 50730 LBS.	O	= FIXED IGNITION 55000 LBS.	■	= FIXED IGNITION 75000 LBS.
□	= FIXED IGNITION 45000 LBS.	X	= FIXED IGNITION 65000 LBS.		

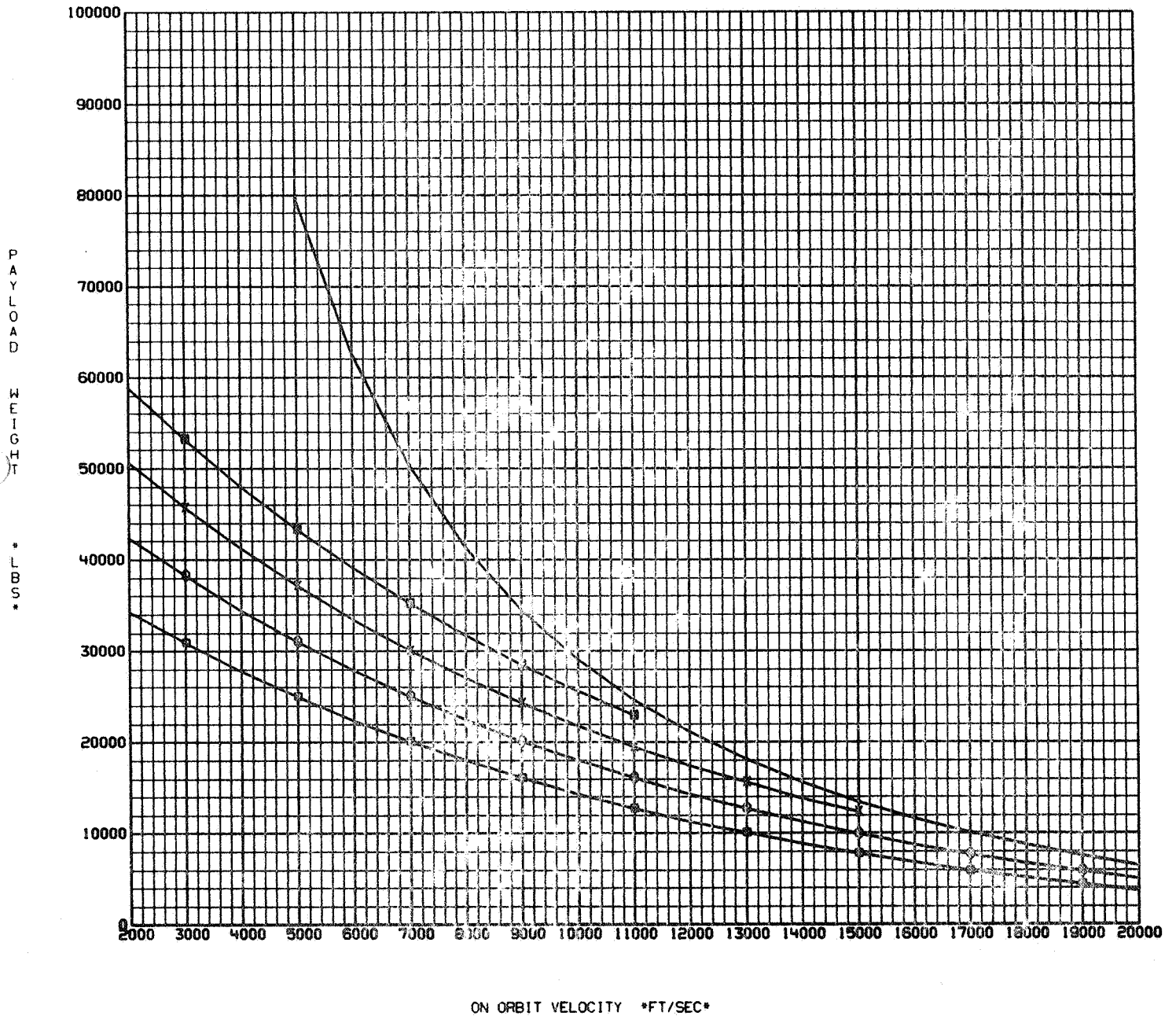
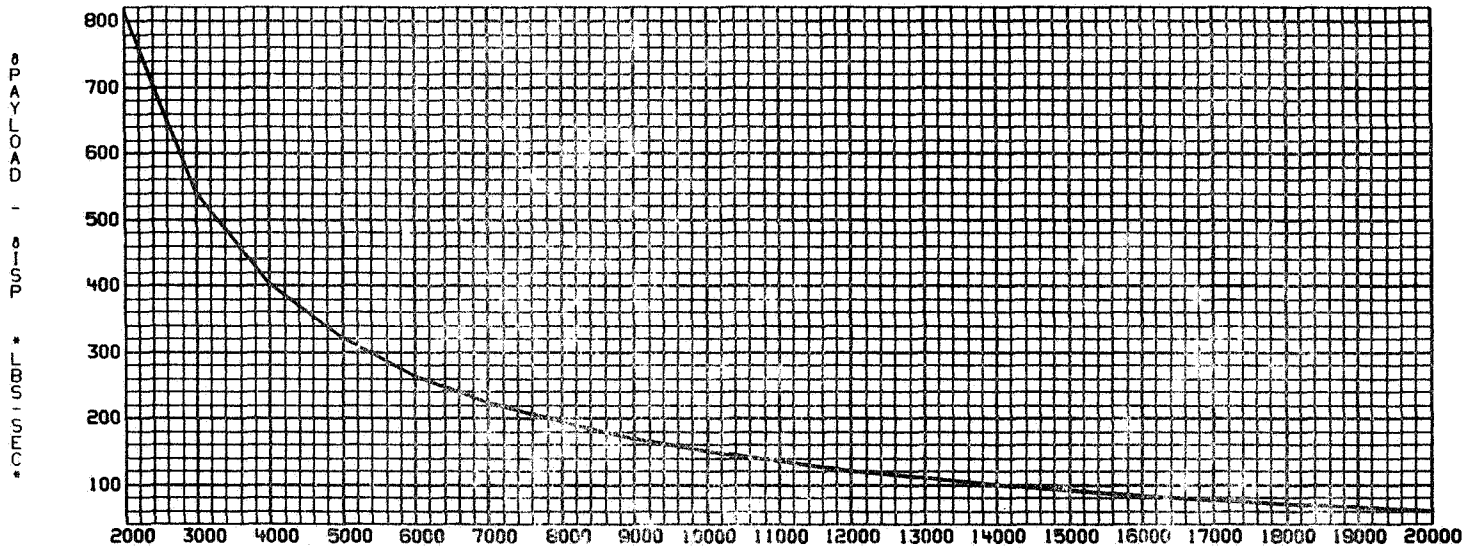


Figure 3-8

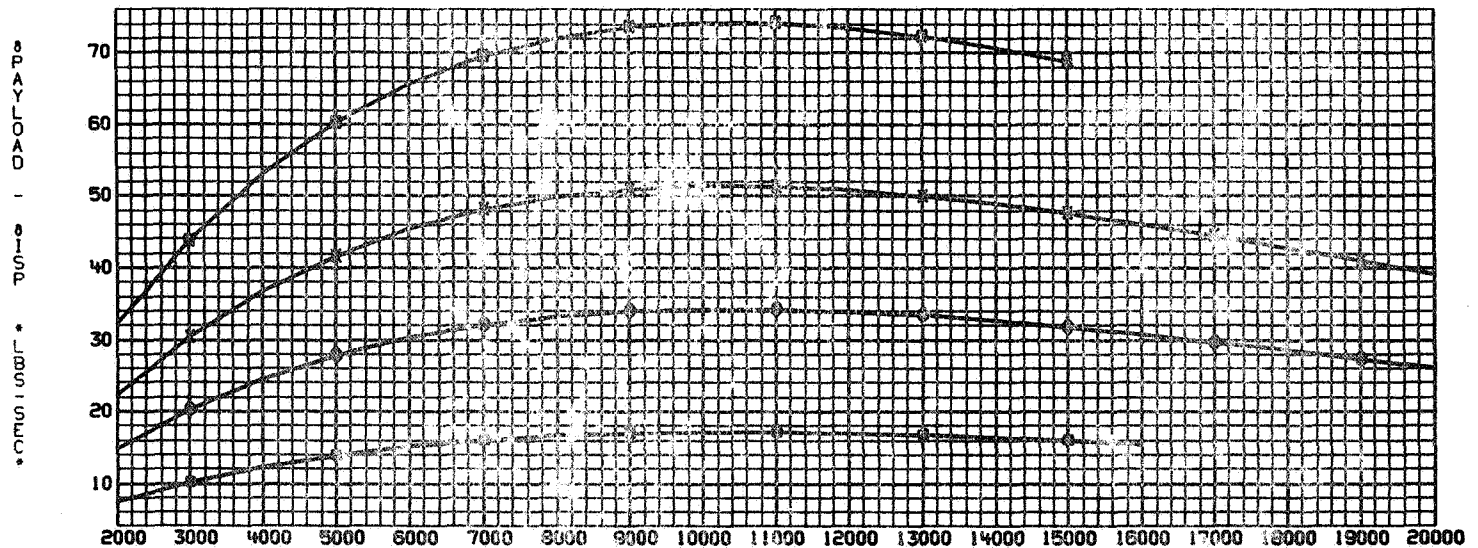
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50730 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
O = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



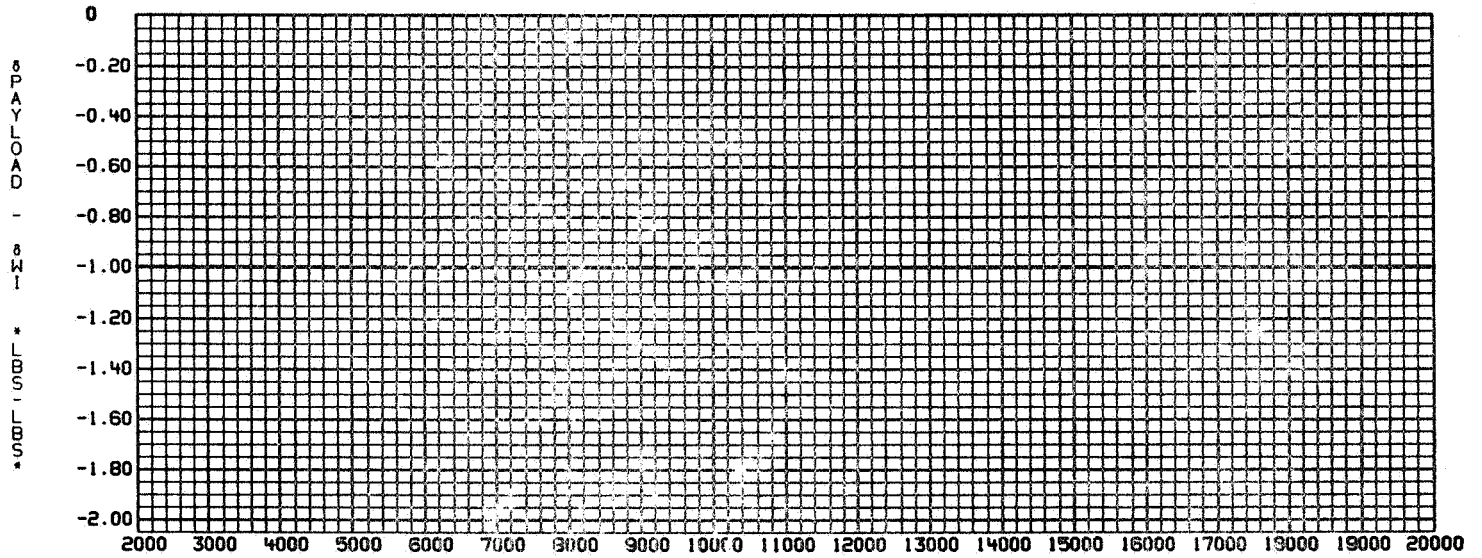
ON ORBIT VELOCITY *FT/SEC*

Figure 3-9

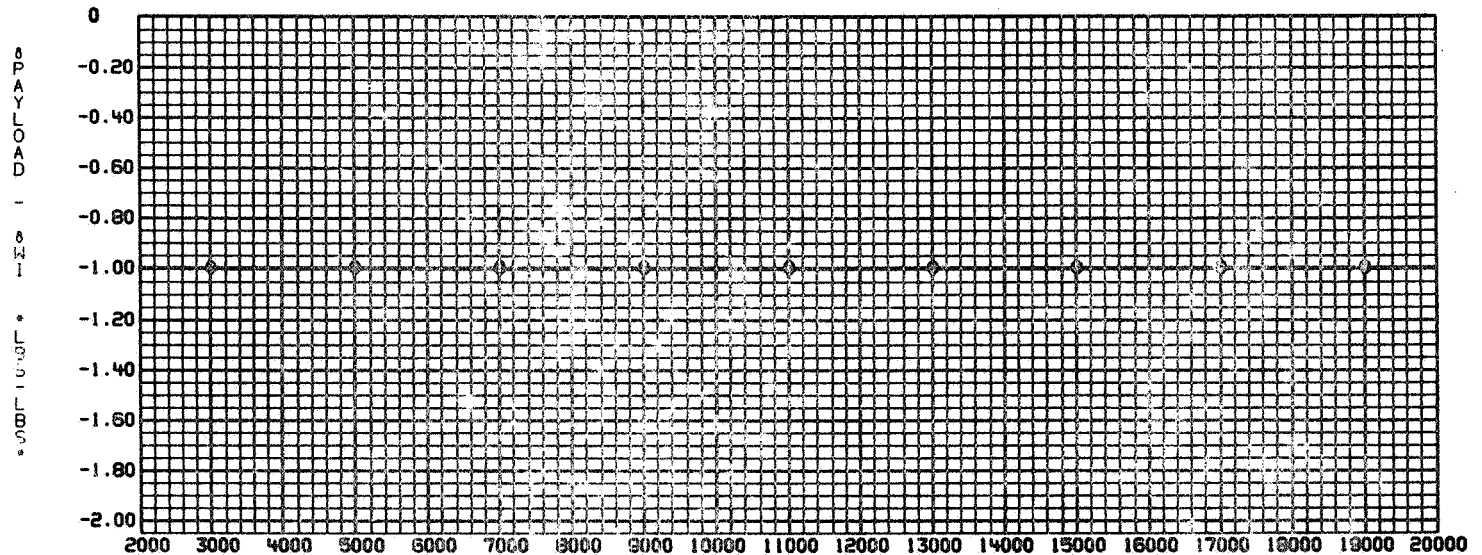
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50730 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-10

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50730 LBS. FIXED PROPELLANT WEIGHT

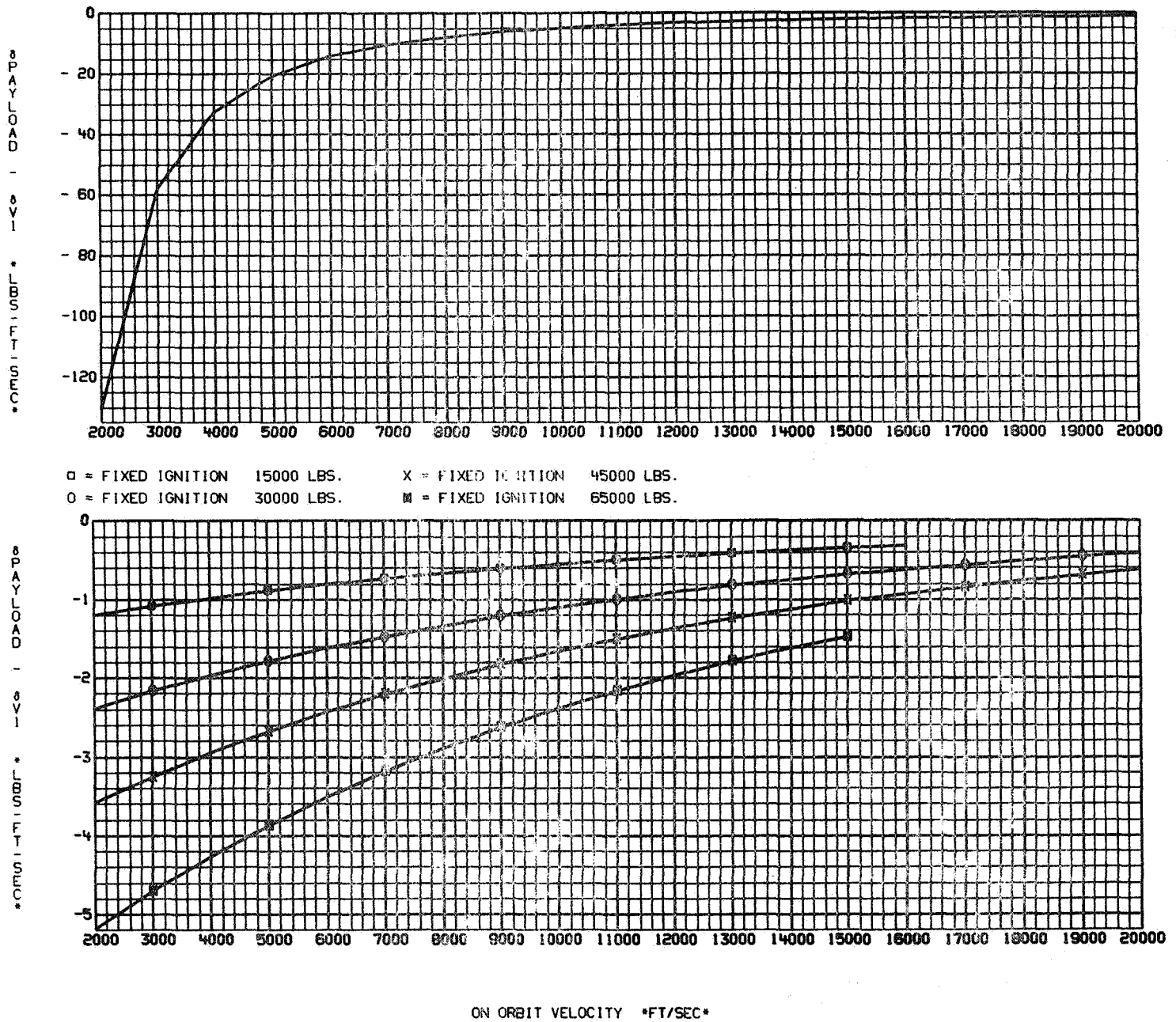


Figure 3-11

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50730 LBS. FIXED PROPELLANT WEIGHT

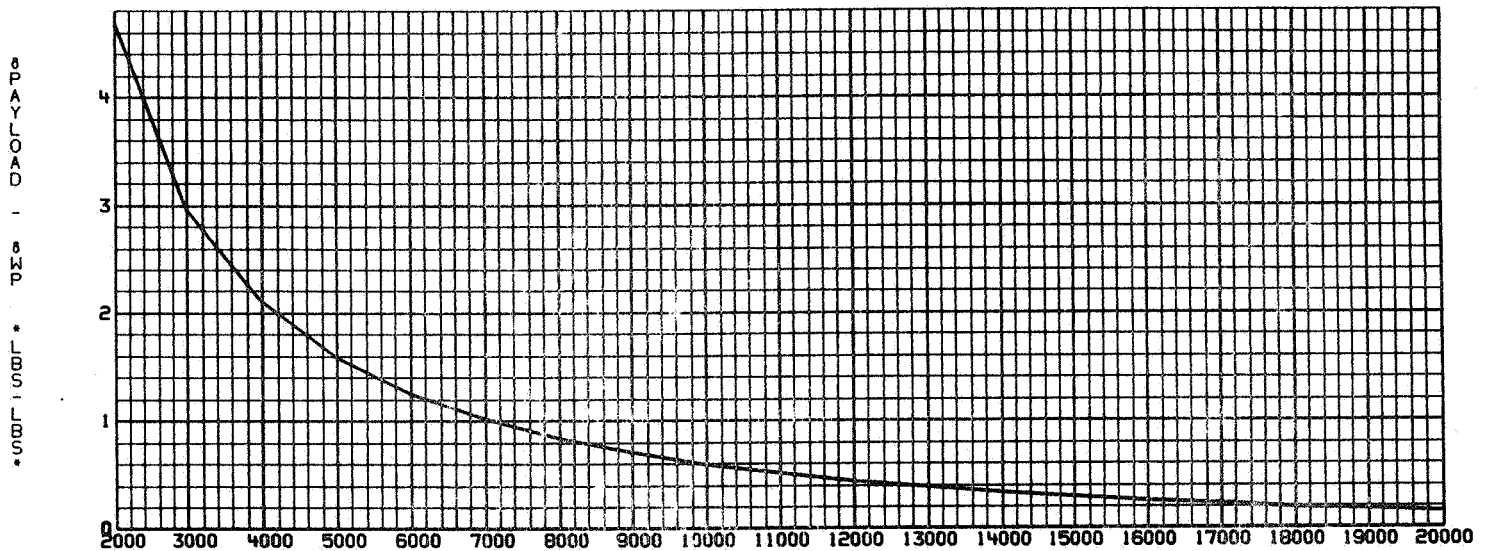


Figure 3-12

ALL FIXED IGNITION WEIGHTS

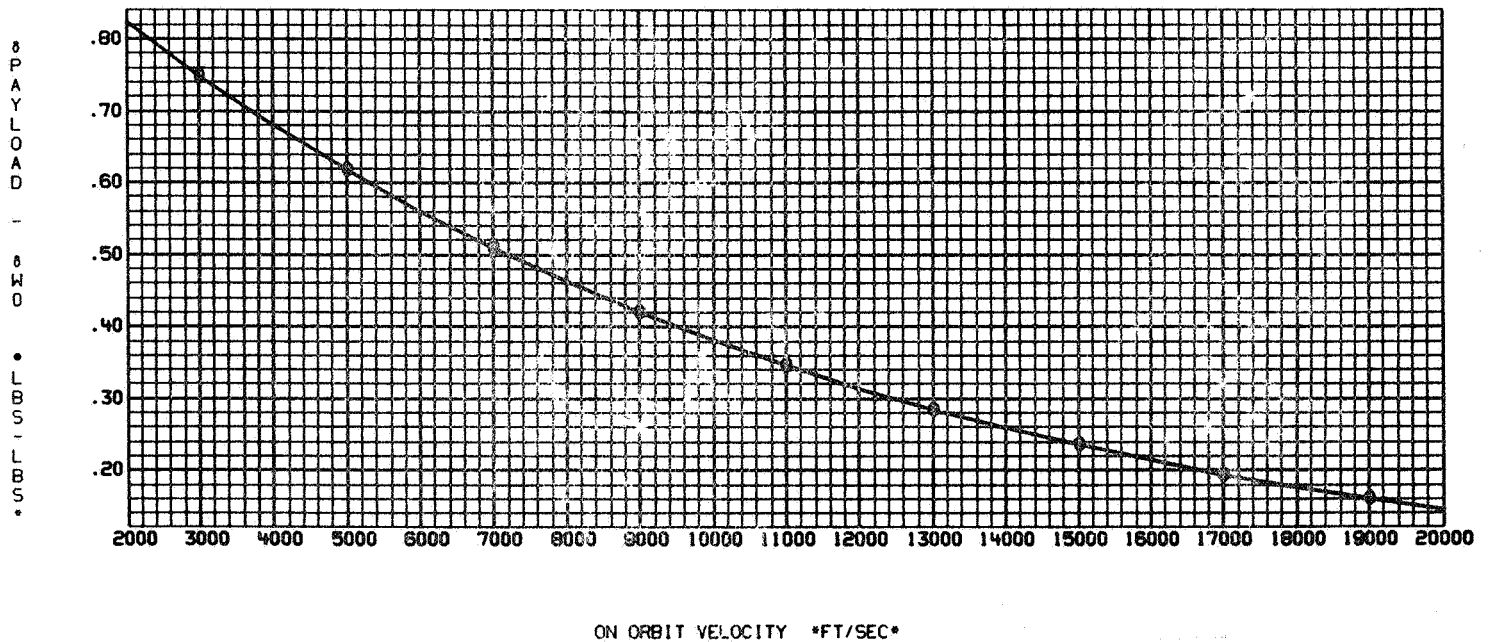


Figure 3-13

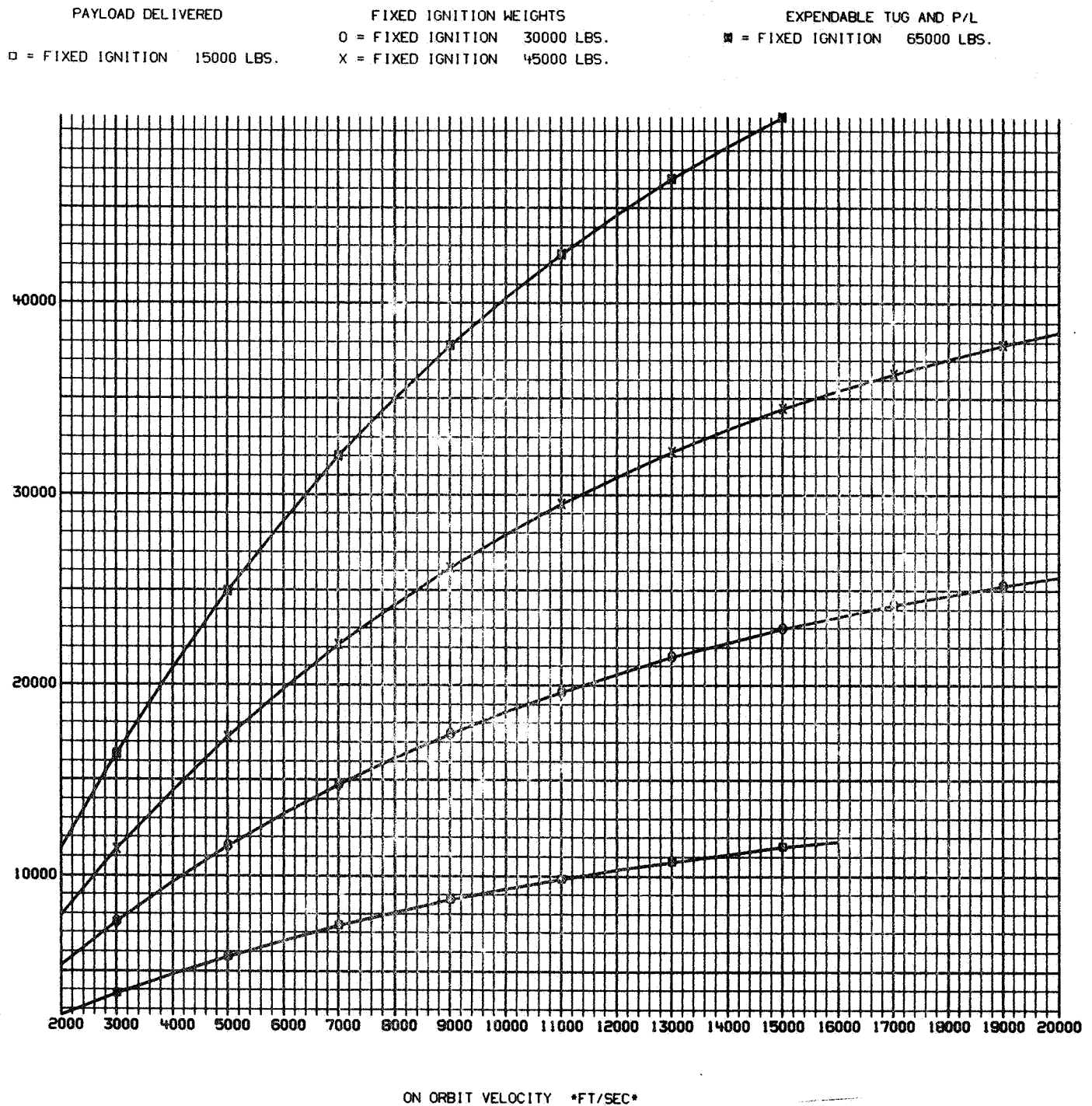


Figure 3-14

D-1T CENTAUR

PAYLOAD DELIVERED		30000 LBS. FIXED PROPELLANT WEIGHT	EXPENDABLE TUG AND P/L
• = FIXED PROPELLANT 30000 LBS.		O = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.		X = FIXED IGNITION 45000 LBS.	

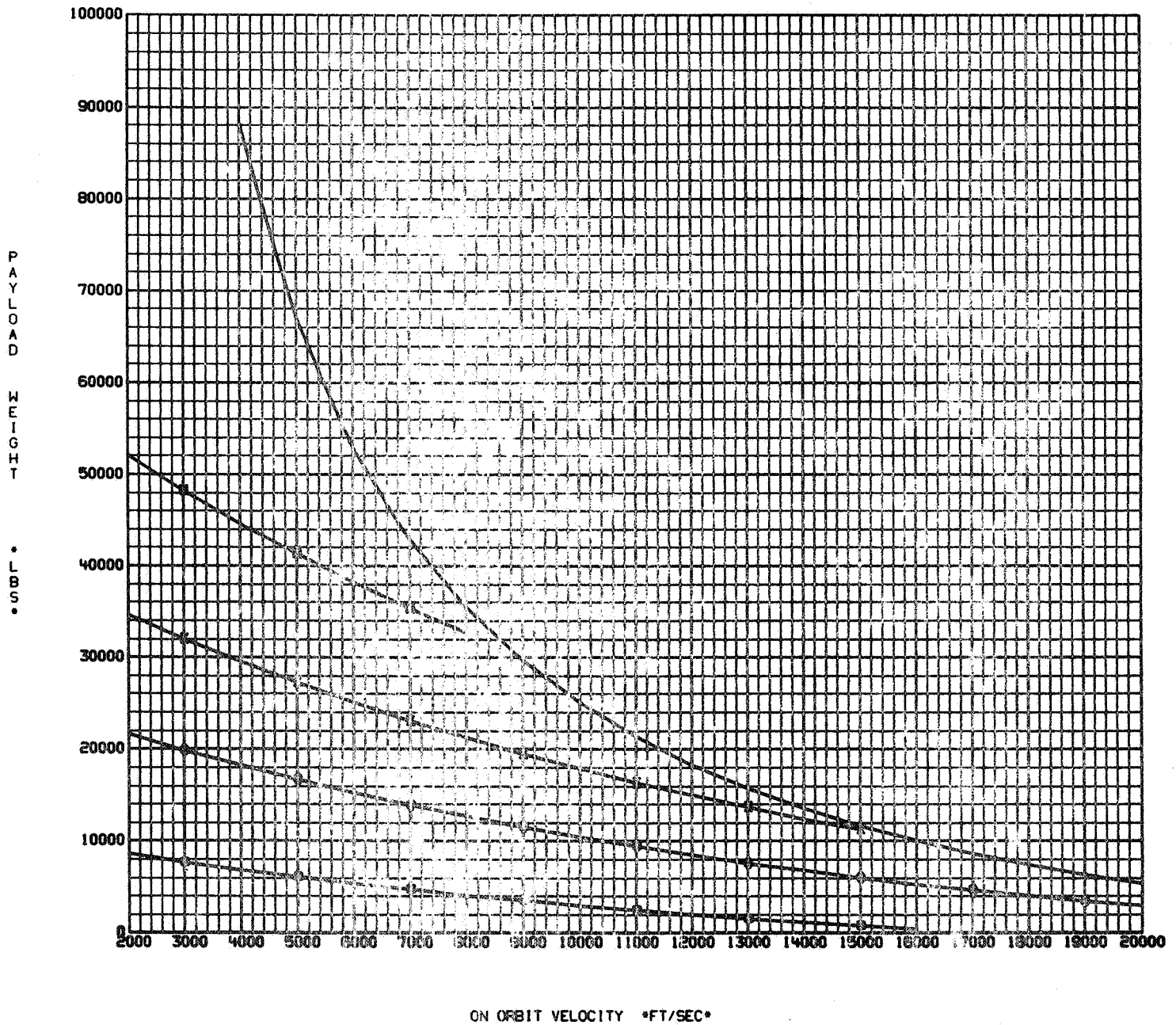
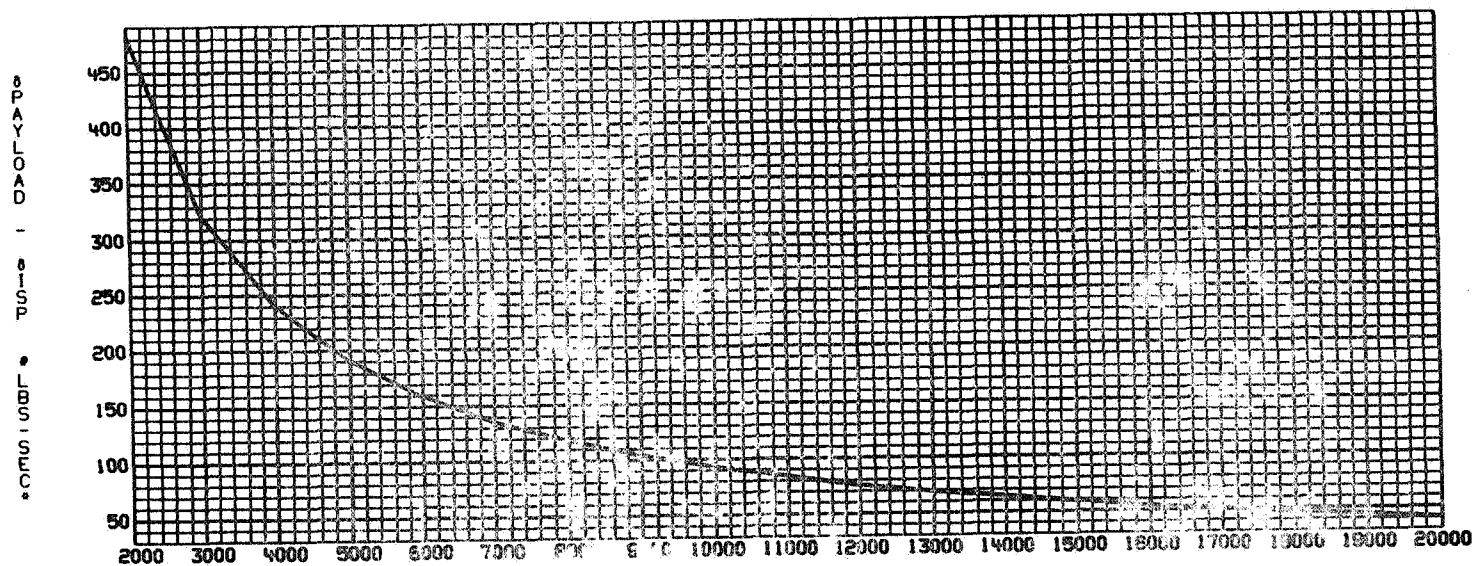


Figure 3-15

PAYLOAD DELIVERED

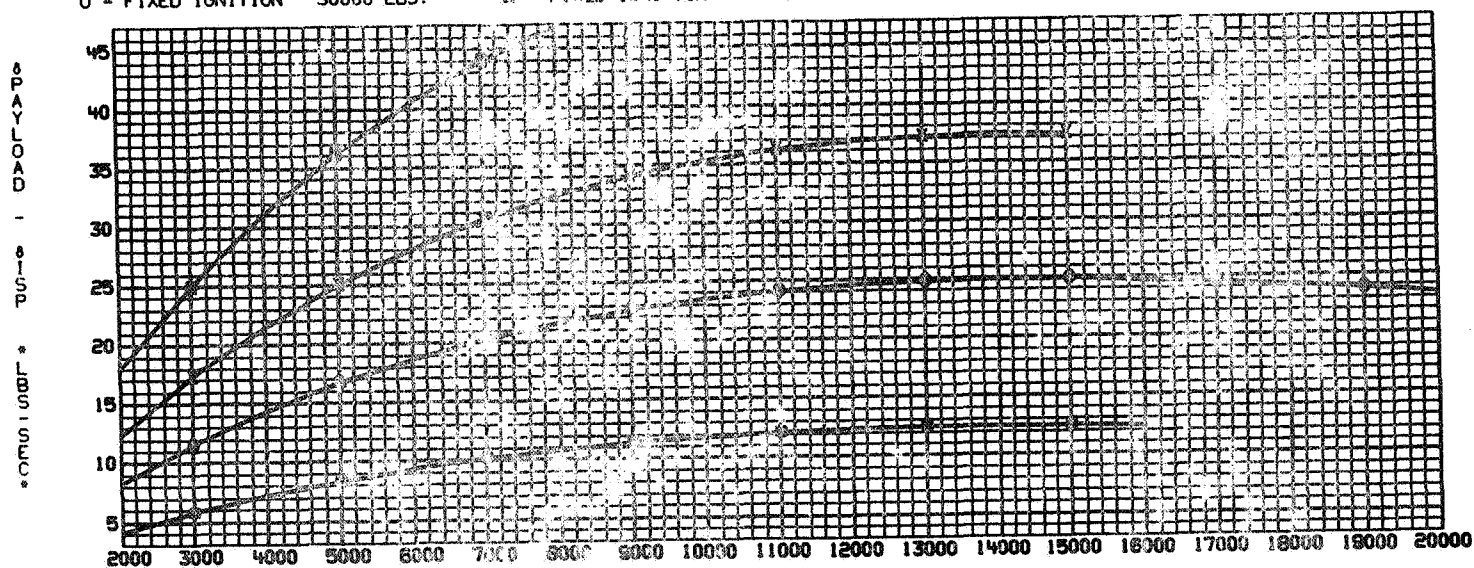
EXPENDABLE TUG AND P/L

30000 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS.
○ = FIXED IGNITION 30000 LBS.

X = FIXED IGNITION 45000 LBS.
■ = FIXED IGNITION 65000 LBS.



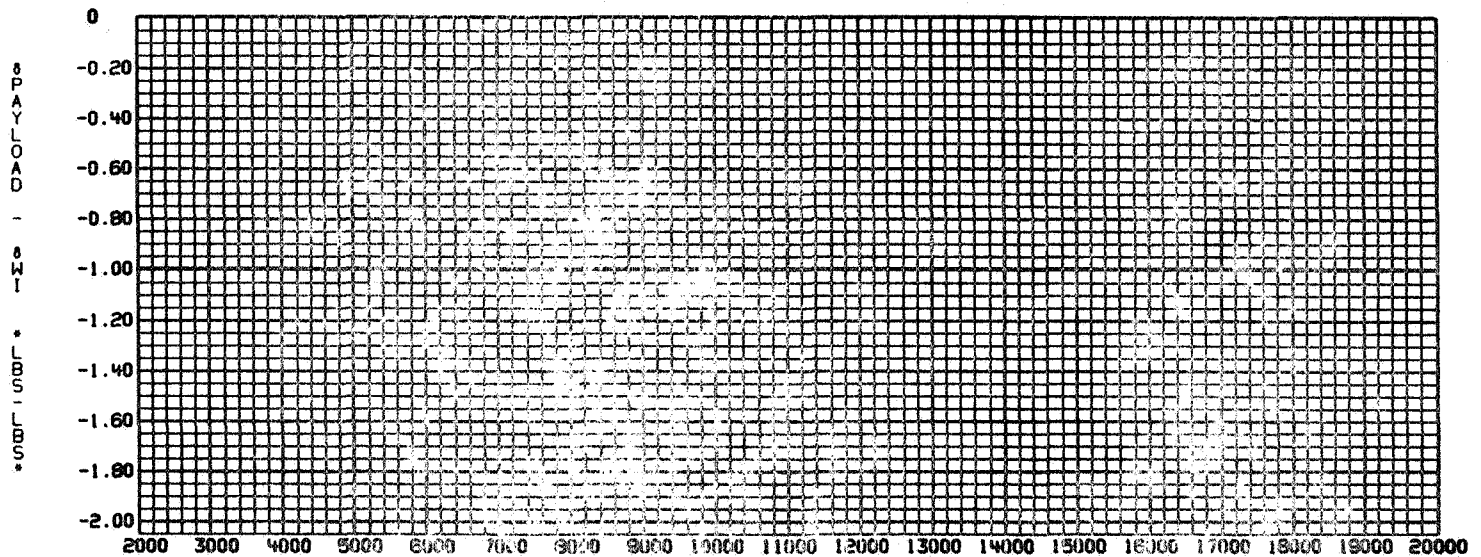
ON ORBIT VELOCITY *FT/SEC*

Figure 3-16

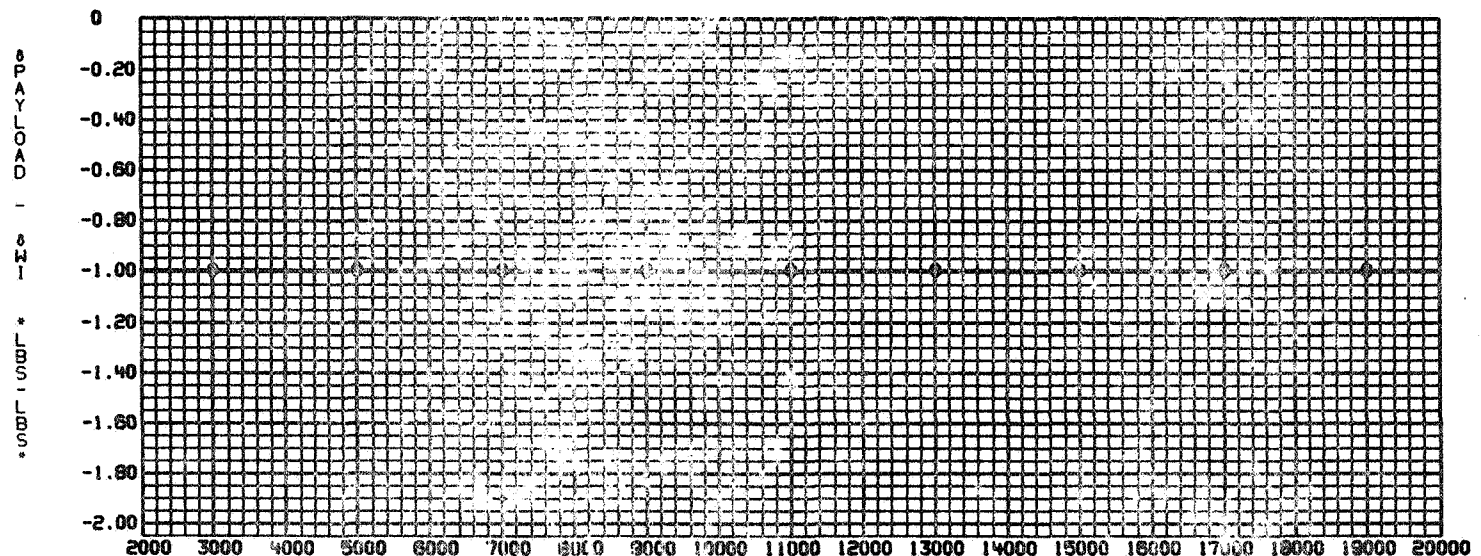
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

30000 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



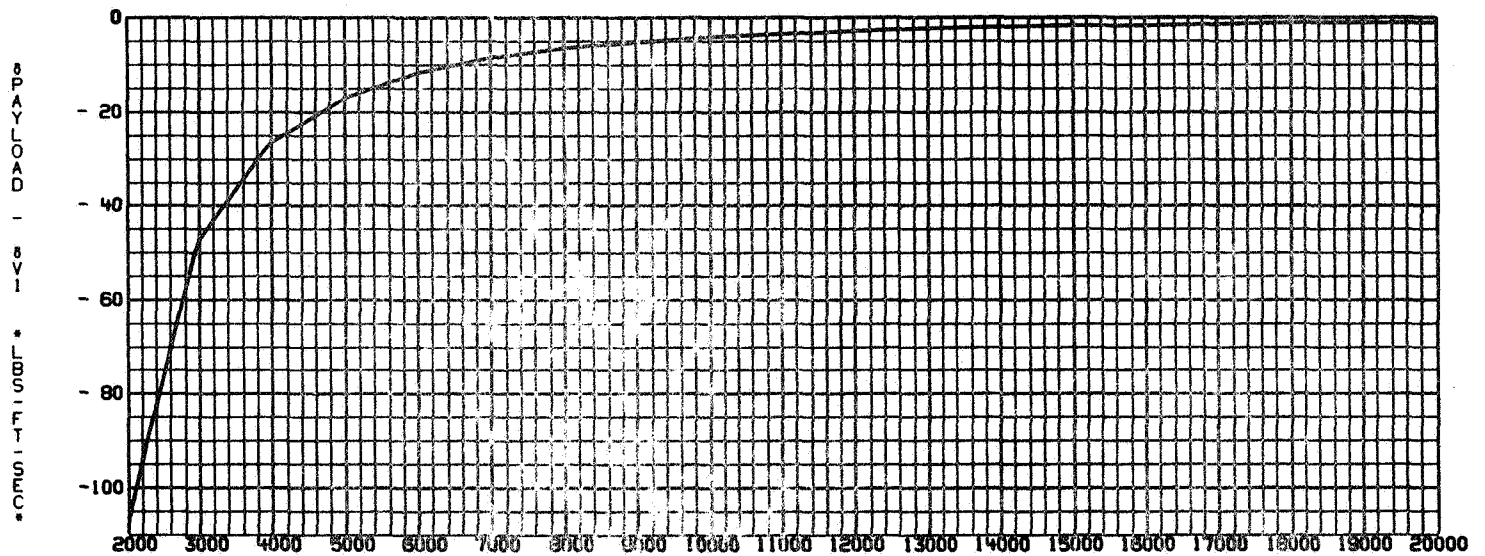
ON ORBIT VELOCITY *FT/SEC*

Figure 3-17

PAYLOAD DELIVERED

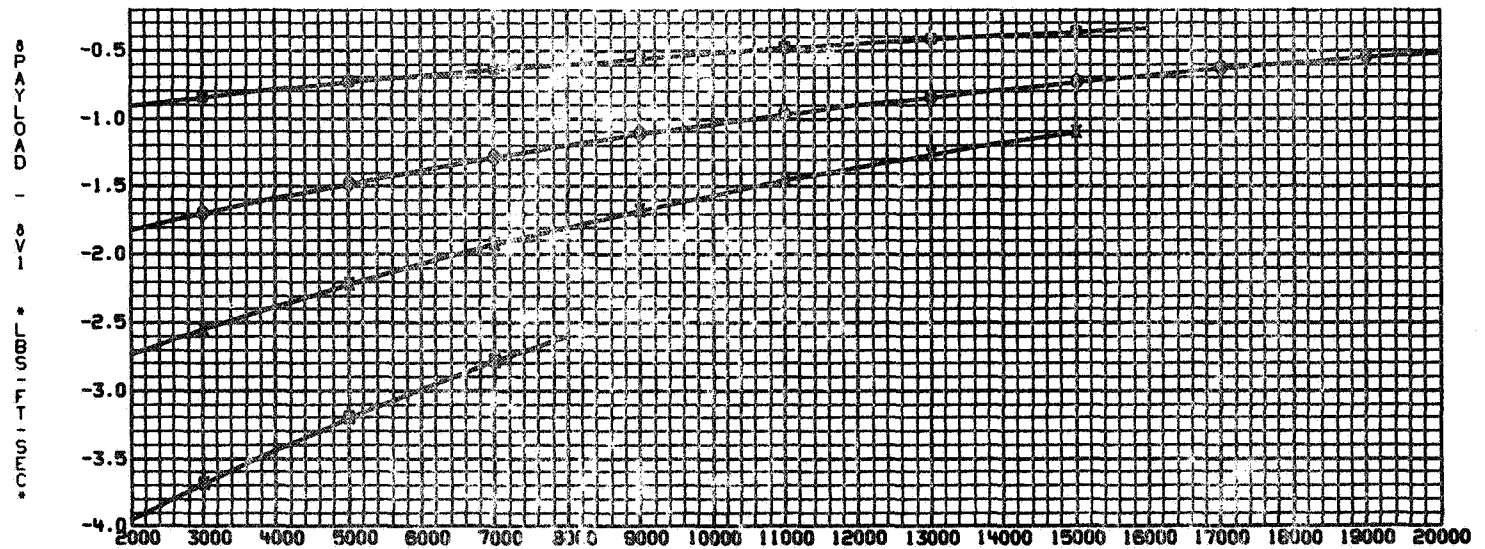
EXPENDABLE TUG AND P/L

30000 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS.
○ = FIXED IGNITION 30000 LBS.

X = FIXED IGNITION 45000 LBS.
■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-18

PAYLOAD DELIVERED
30000 LBS. FIXED PROPELLANT WEIGHT

EXPENDABLE TUG AND P/L

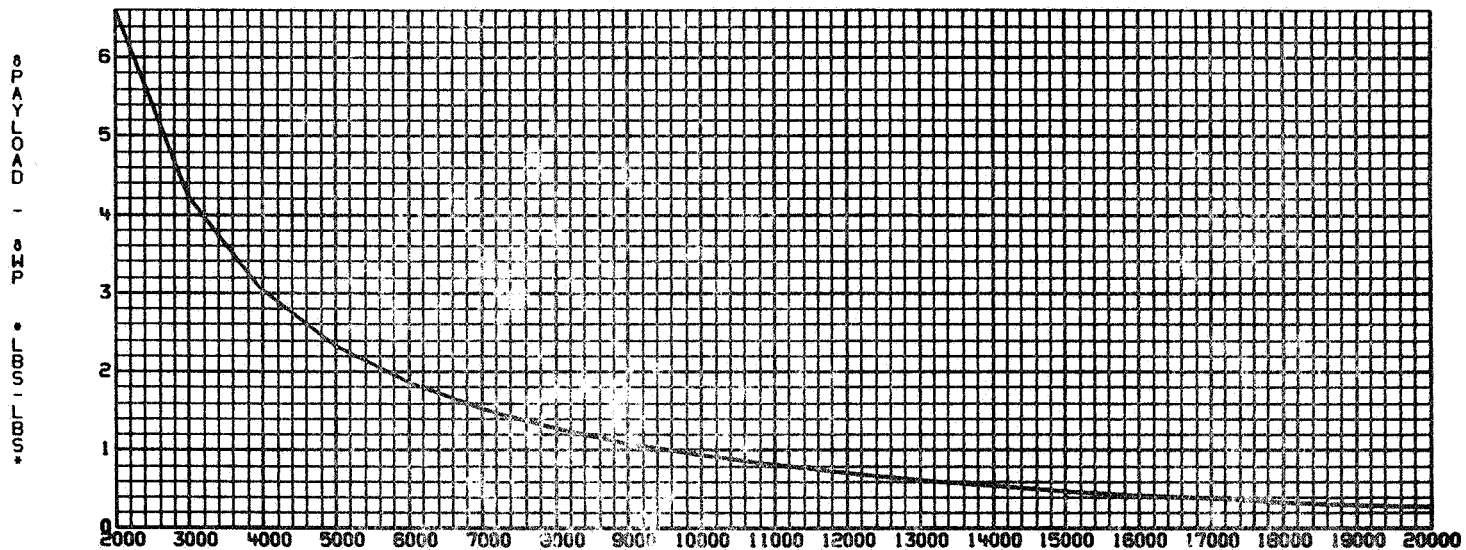


Figure 3-19

ALL FIXED IGNITION WEIGHTS

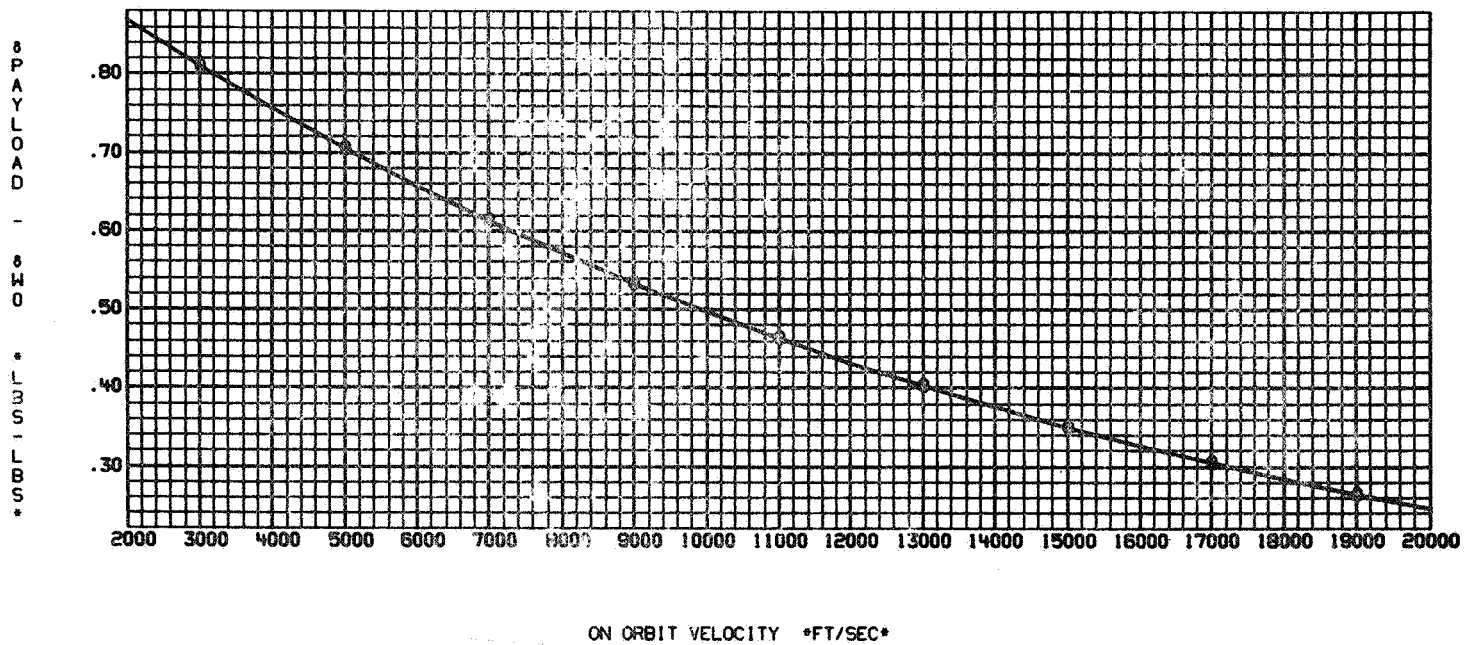


Figure 3-20

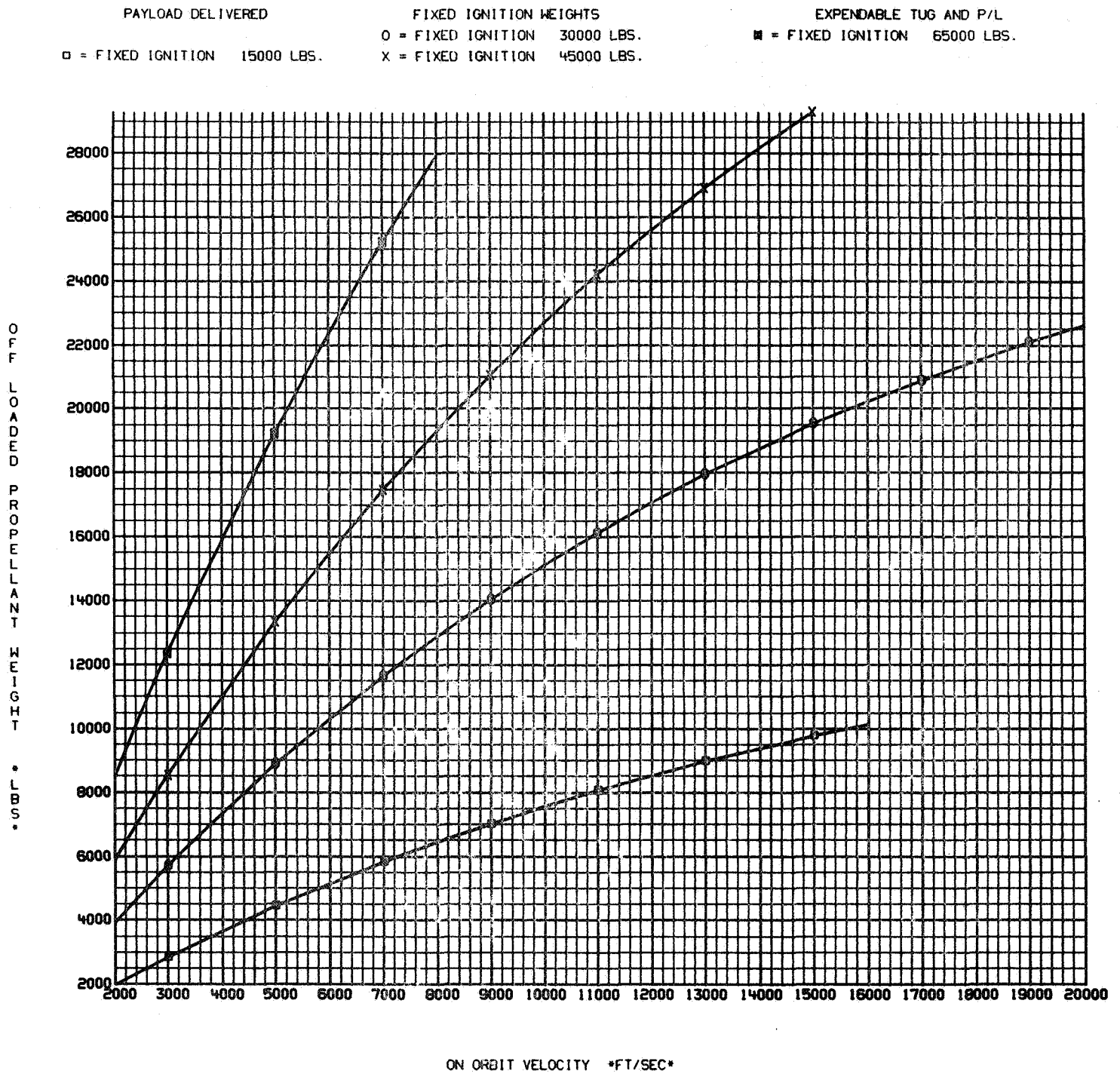


Figure 3-21

GT CENTAUR
 $W_p = 45,000 \text{ LB}$

PAYLOAD DELIVERED
• = FIXED PROPELLANT 45000 LBS.
◻ = FIXED IGNITION 15000 LBS.

45000 LBS. FIXED PROPELLANT WEIGHT
O = FIXED IGNITION 30000 LBS.
X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L
■ = FIXED IGNITION 65000 LBS.

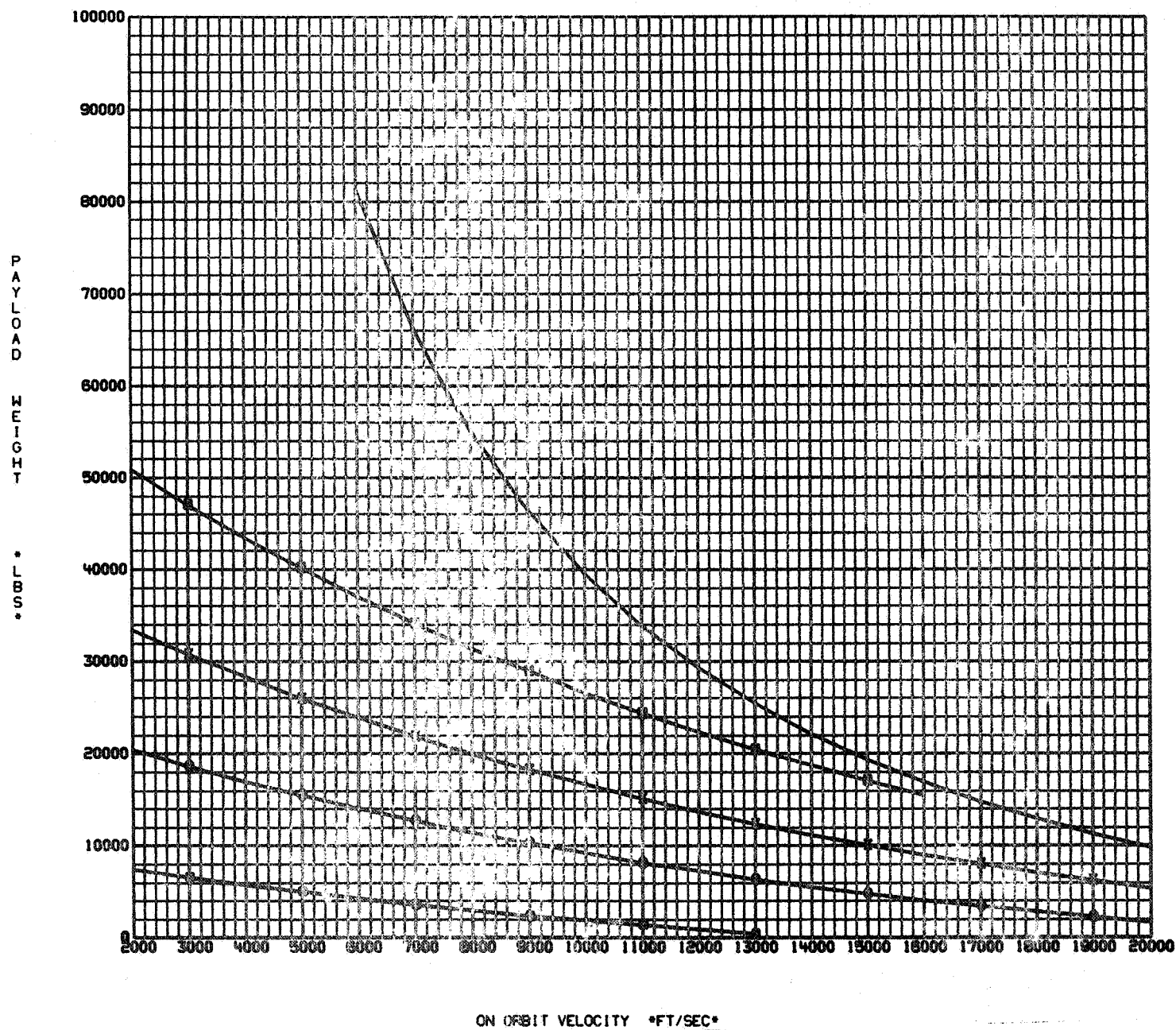
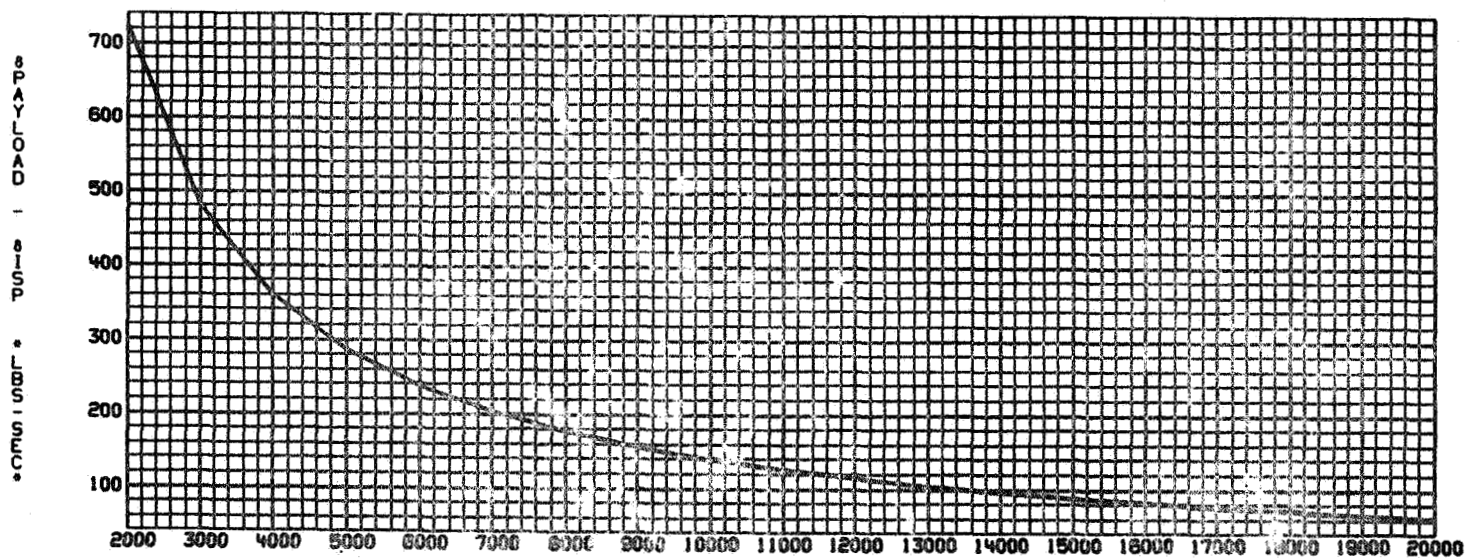


Figure 3-22

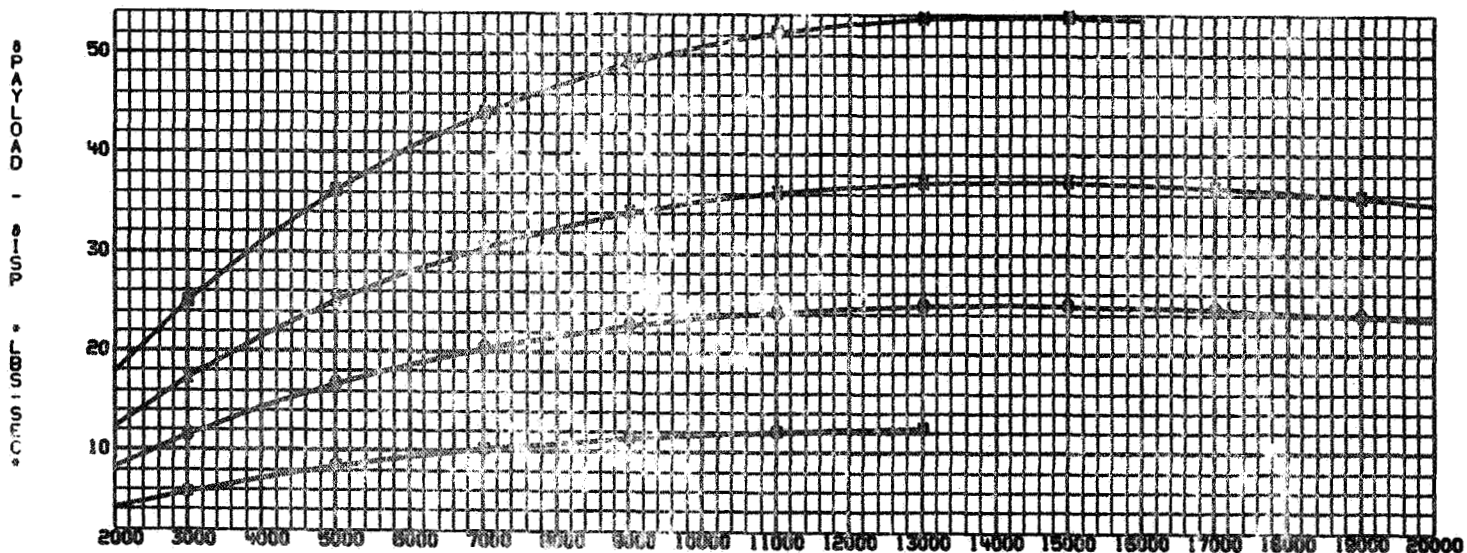
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

45000 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-23

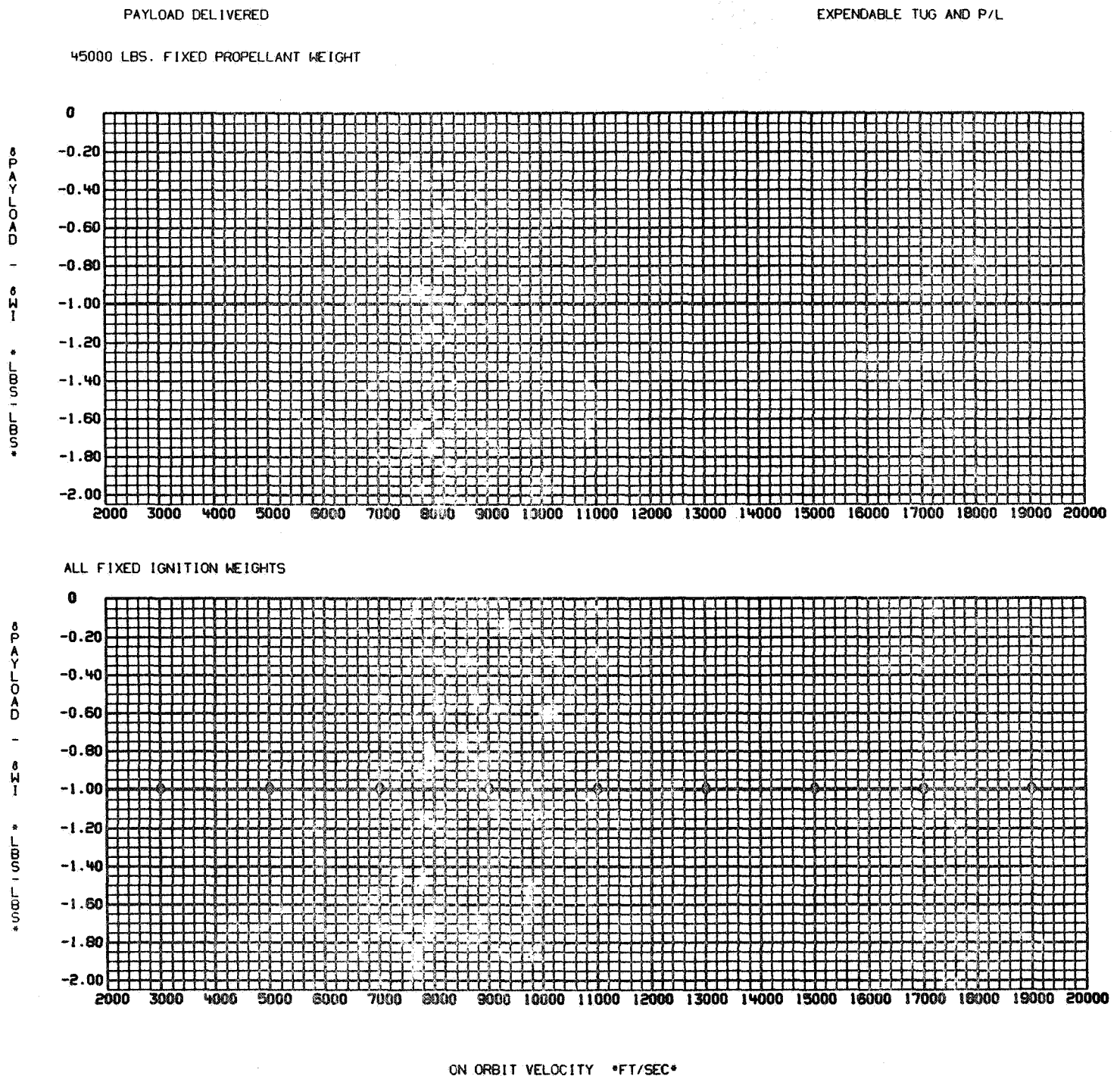
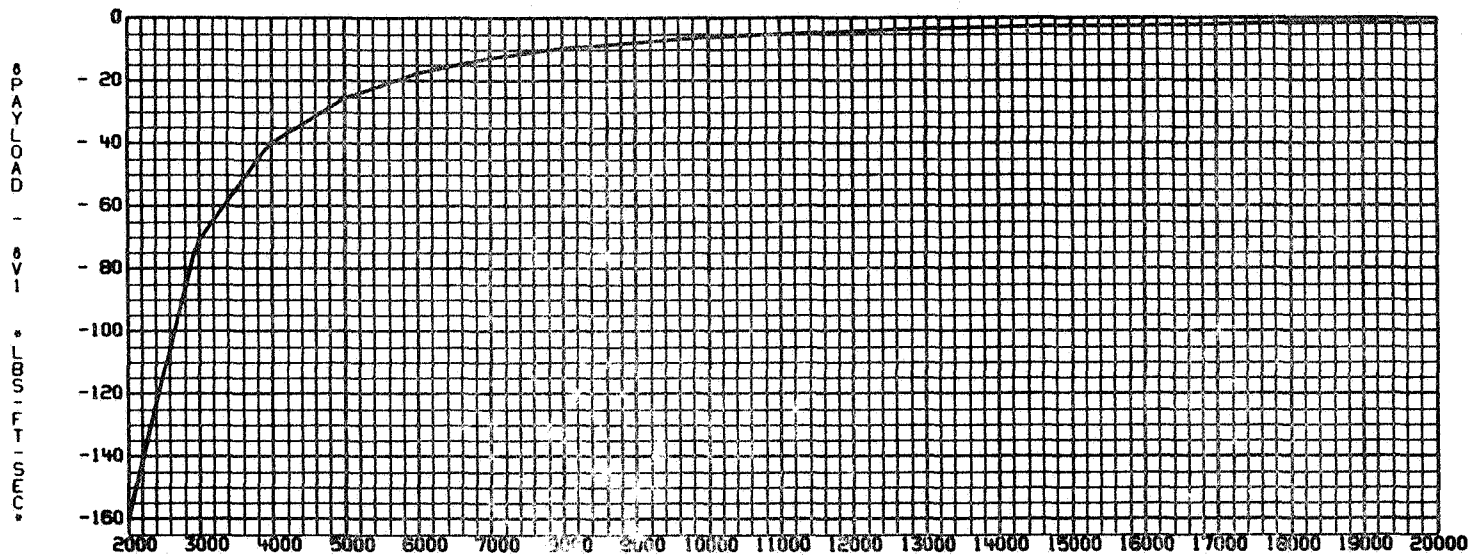


Figure 3-24

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

45000 LBS. FIXED PROPELLANT WEIGHT



a = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 O = FIXED IGNITION 30000 LBS. □ = FIXED IGNITION 65000 LBS.

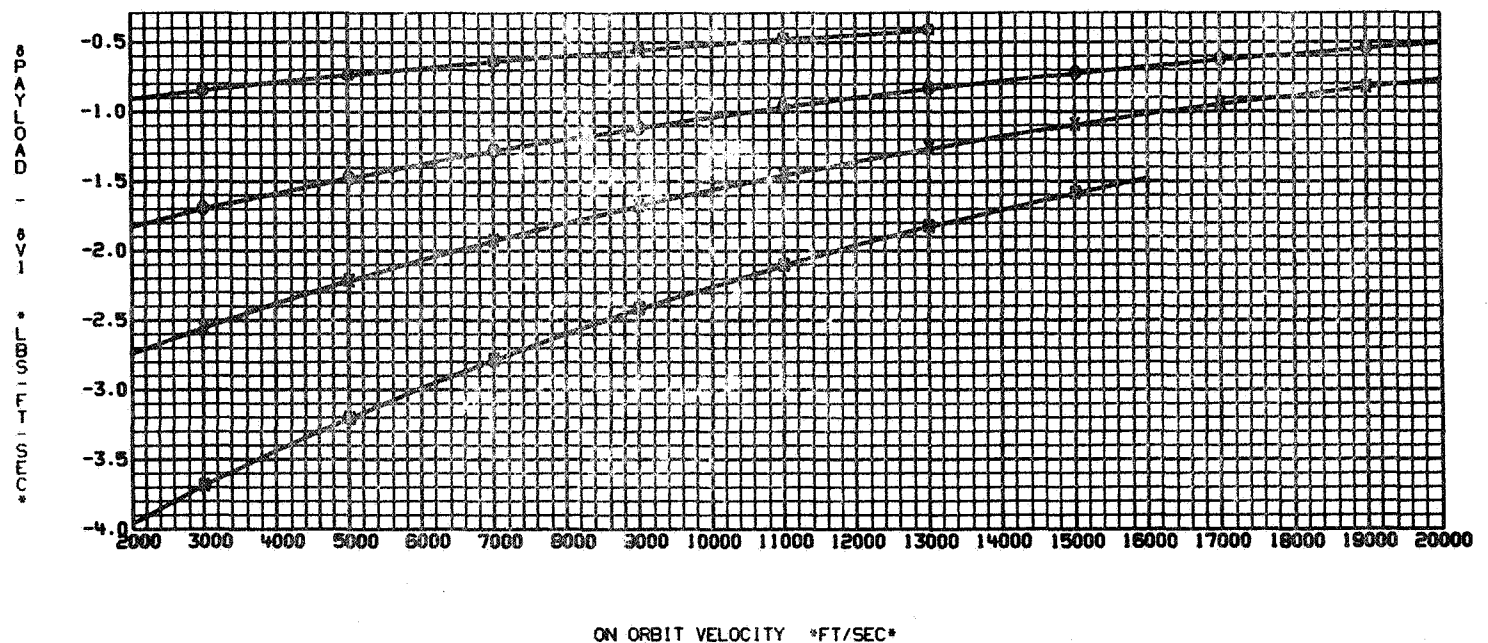


Figure 3-25

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

45000 LBS. FIXED PROPELLANT WEIGHT

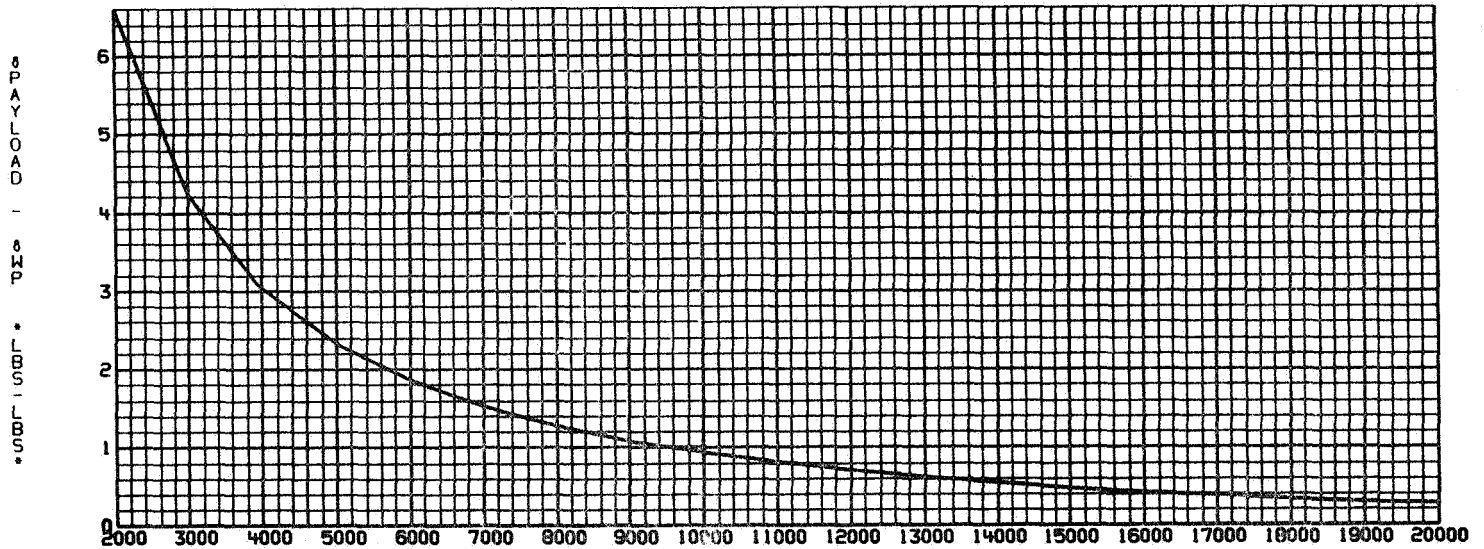


Figure 3-26

ALL FIXED IGNITION WEIGHTS

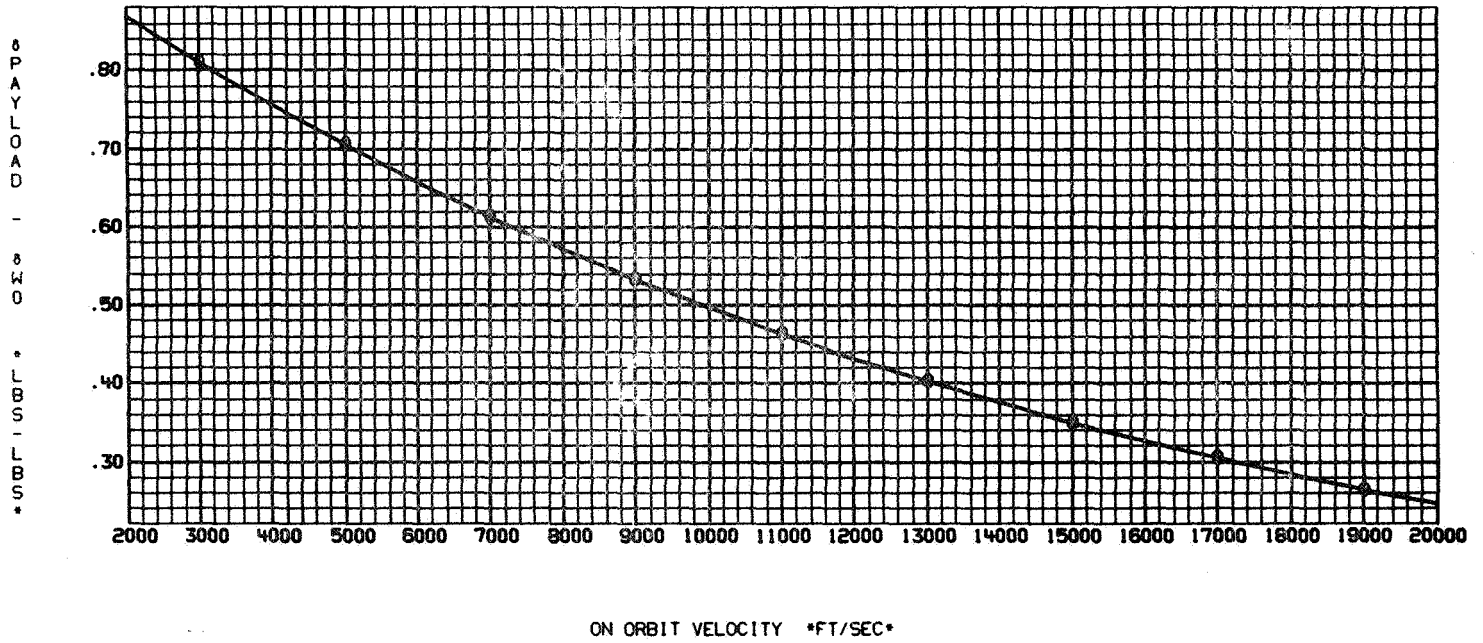


Figure 3-27

PAYLOAD DELIVERED
 ○ = FIXED PROPELLANT 45000 LBS.
 □ = FIXED IGNITION 45000 LBS.

45000 LBS. FIXED PROPELLANT WEIGHT
 ○ = FIXED IGNITION 55000 LBS.
 X = FIXED IGNITION 65000 LBS.

EXPENDABLE TUG AND P/L
 ■ = FIXED IGNITION 75000 LBS.

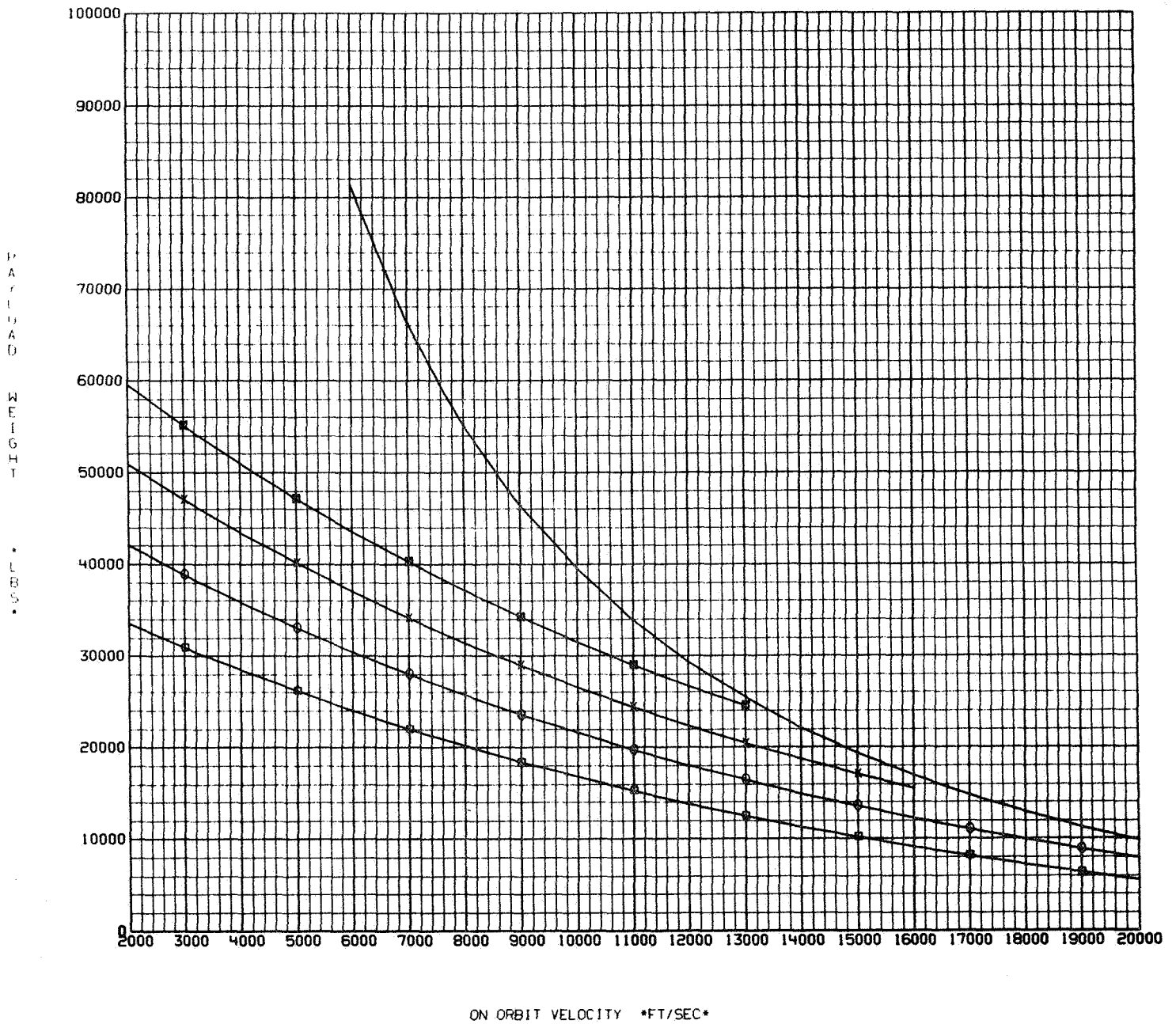


Figure 3-28

MODE 1

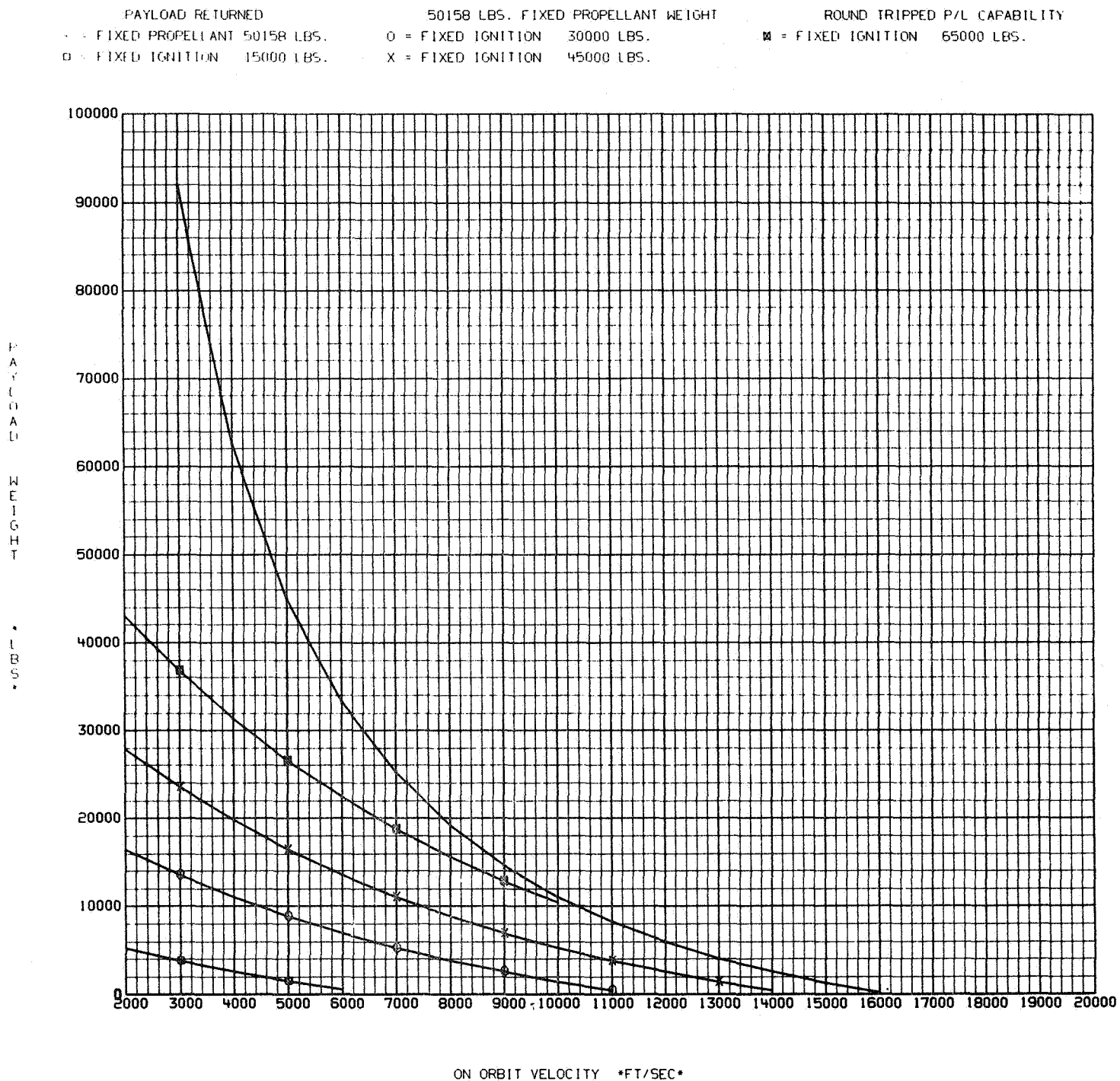
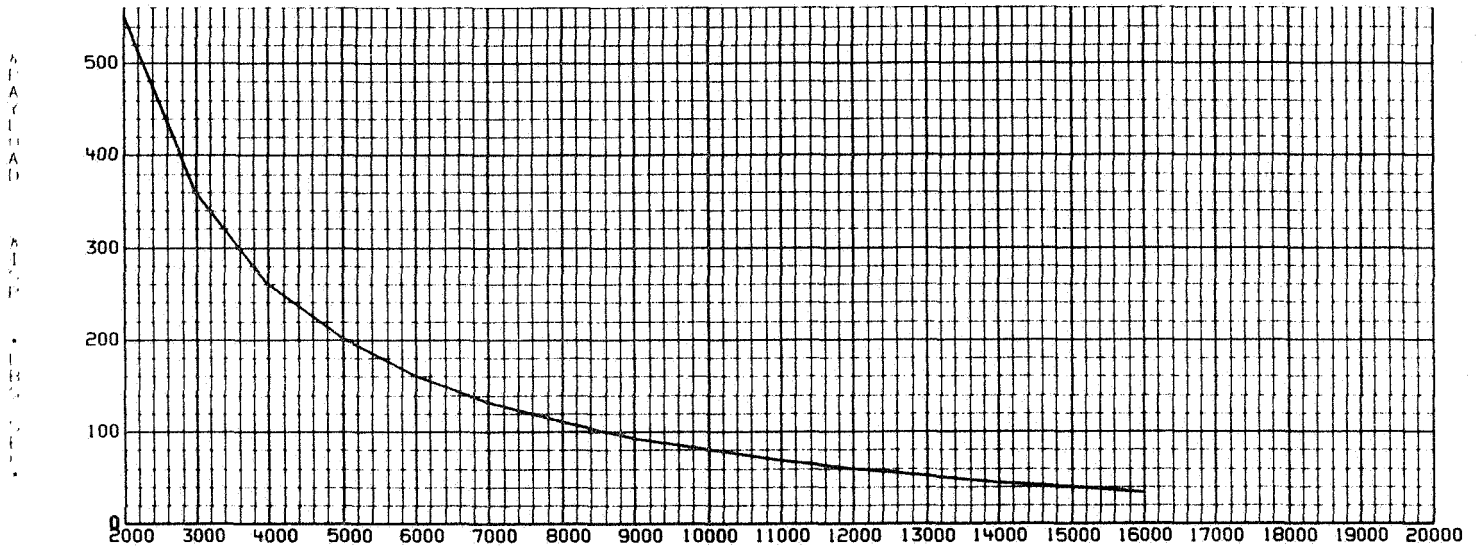


Figure 3-29

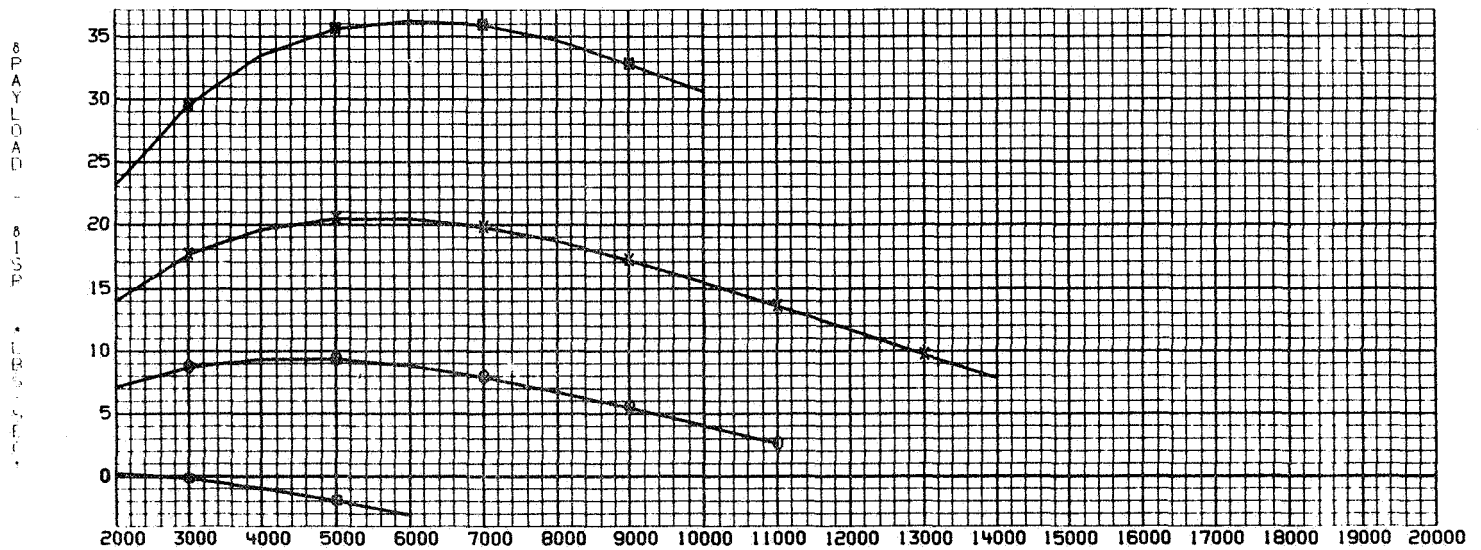
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT



O = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 O = FIXED IGNITION 30000 LBS. X = FIXED IGNITION 65000 LBS.



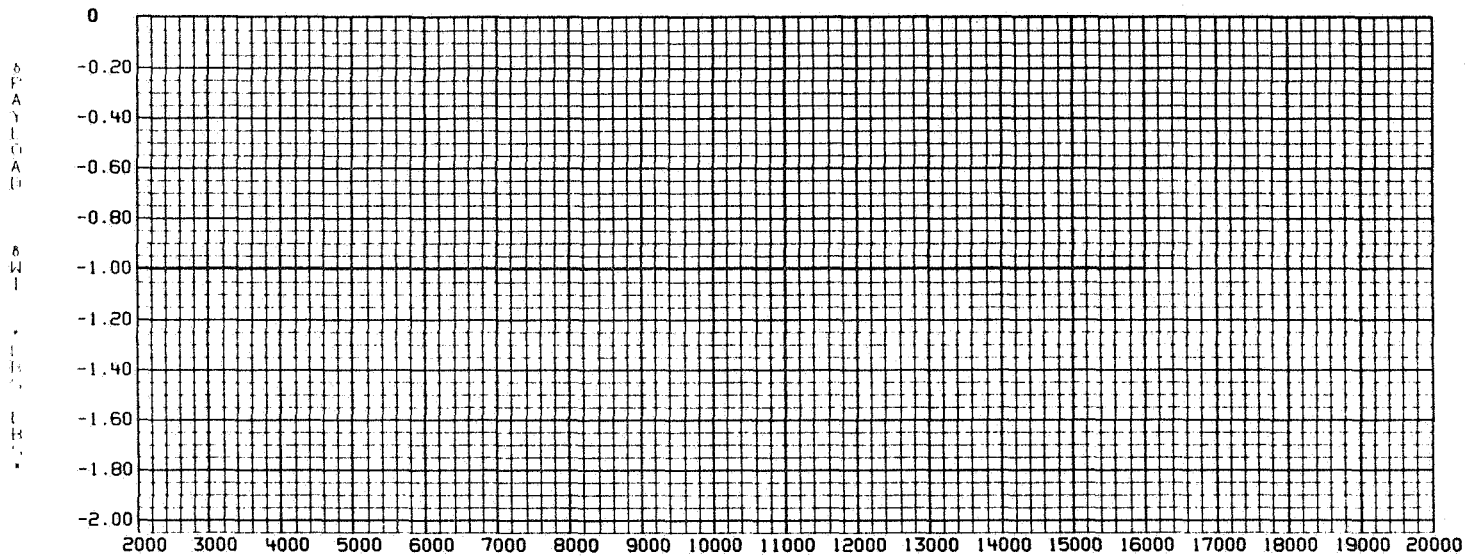
ON ORBIT VELOCITY *FT/SEC*

Figure 3-30

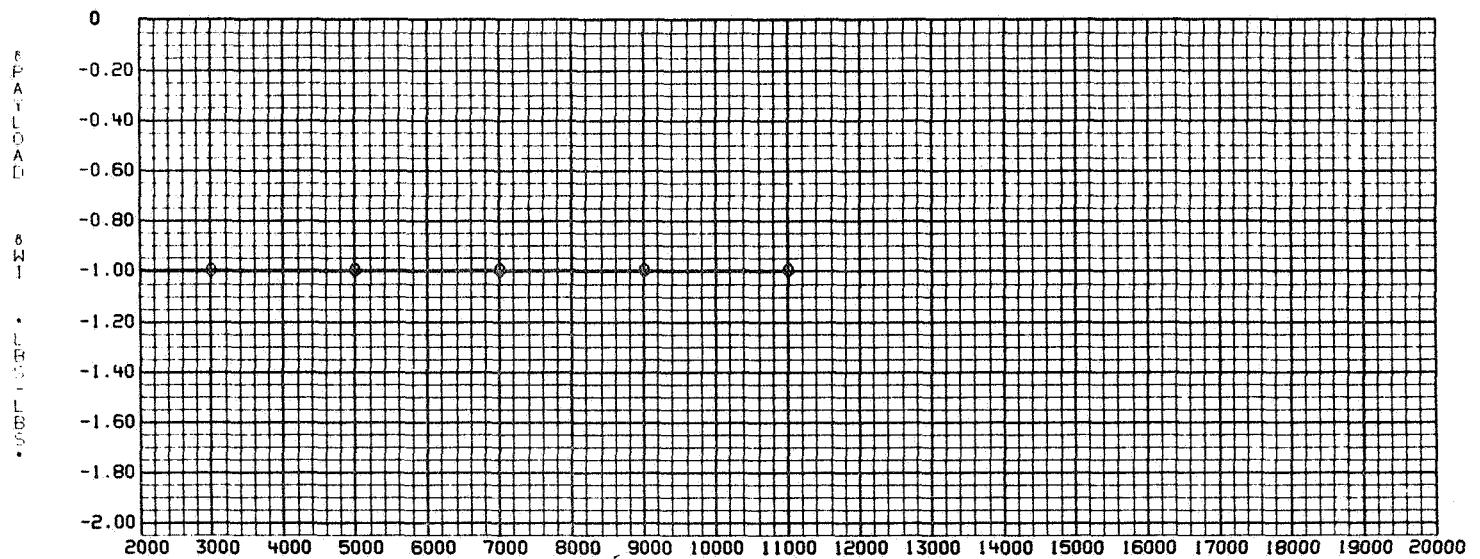
PAYLOAD DELIVERED

ROUND TRIPED P/L CAPABILITY

EXCEEDING FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



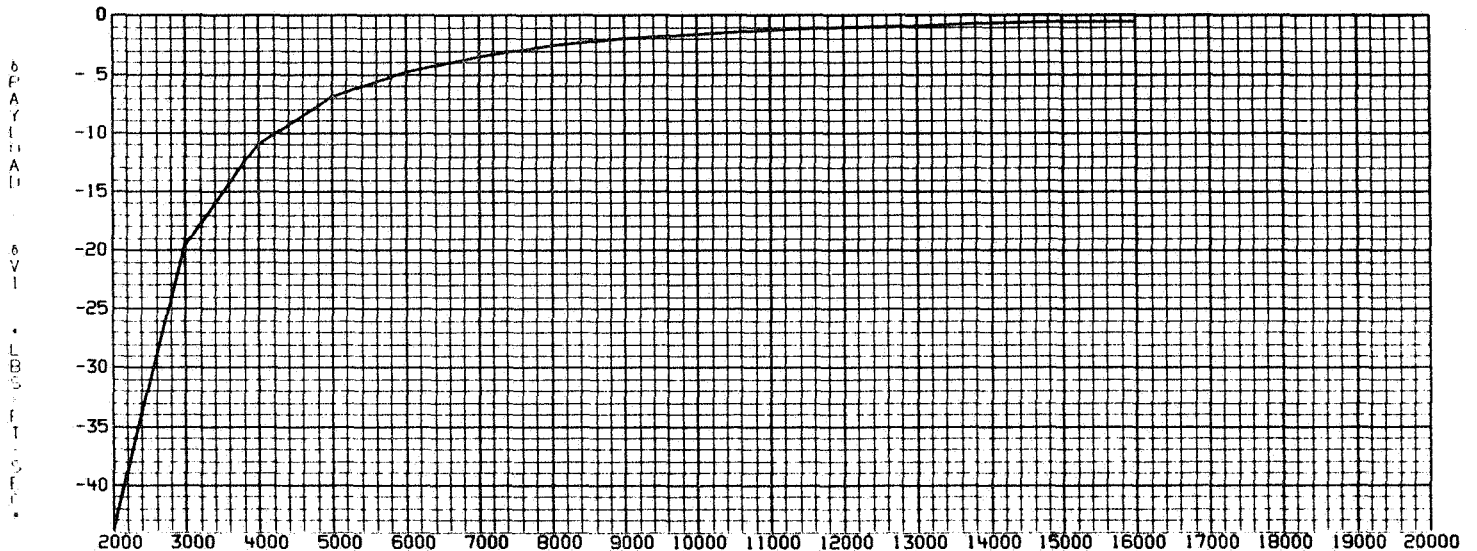
ON ORBIT VELOCITY *FT/SEC*

Figure 3-31

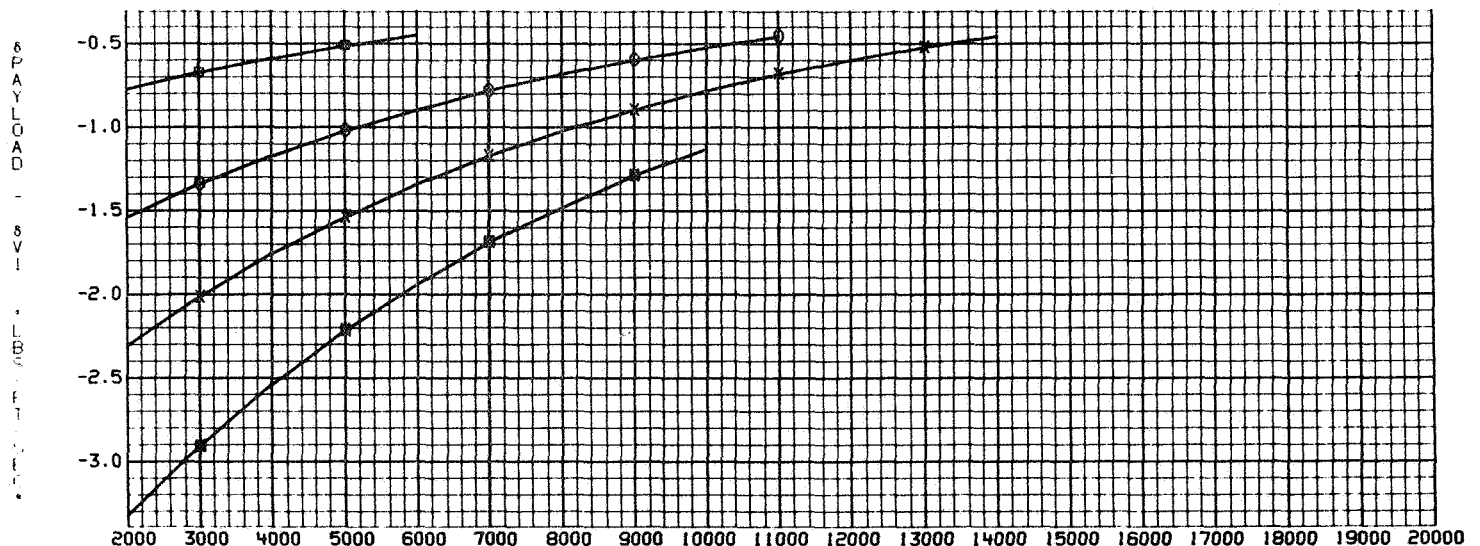
PAYLOAD DELIVERED

ROUND TRIPED P-I CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



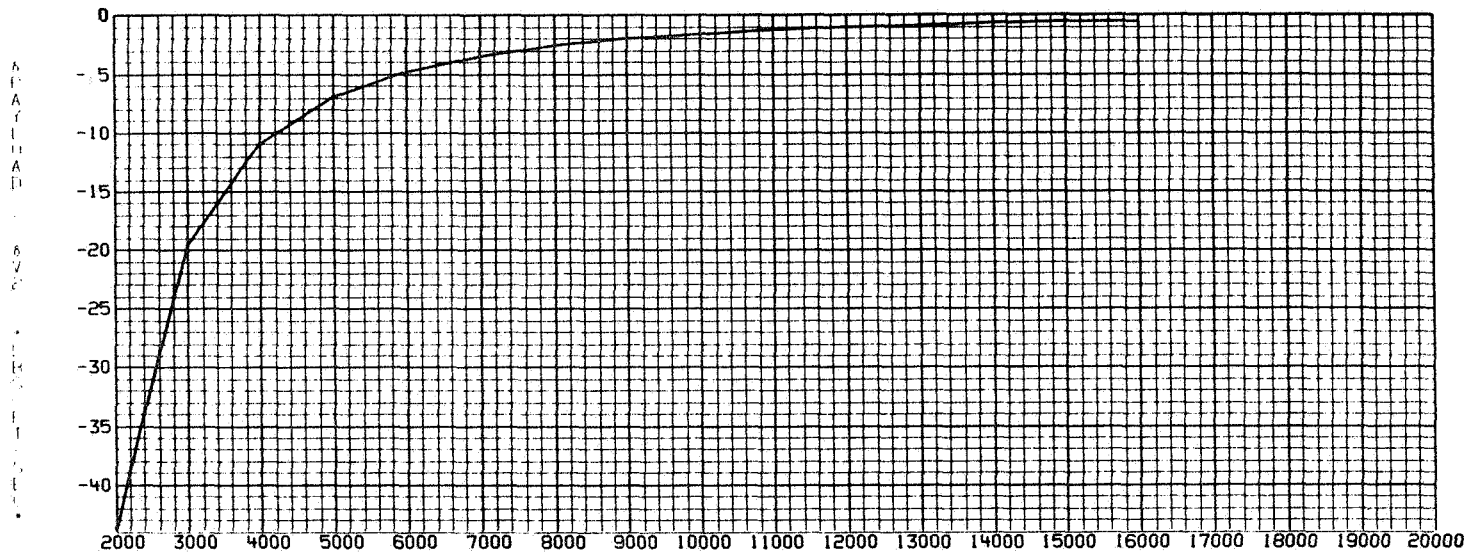
ON ORBIT VELOCITY *FT/SEC*

Figure 3-32

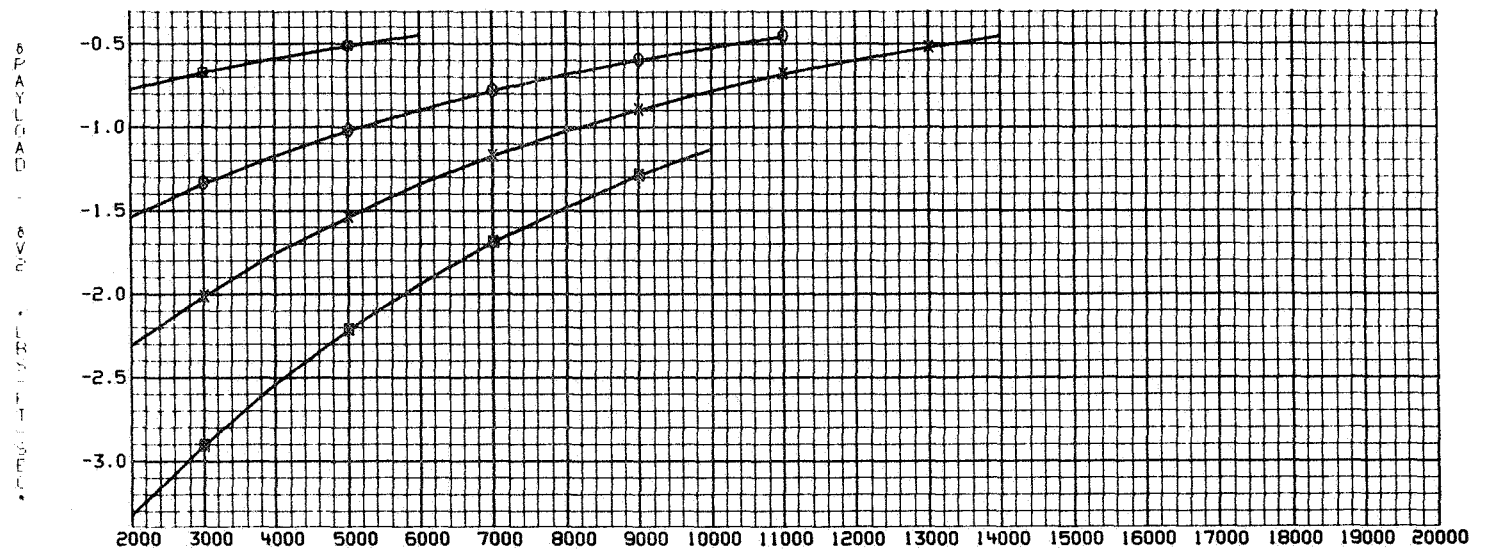
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

MISSILE FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-33

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

50193 LBS. FIXED PROPELLANT WEIGHT

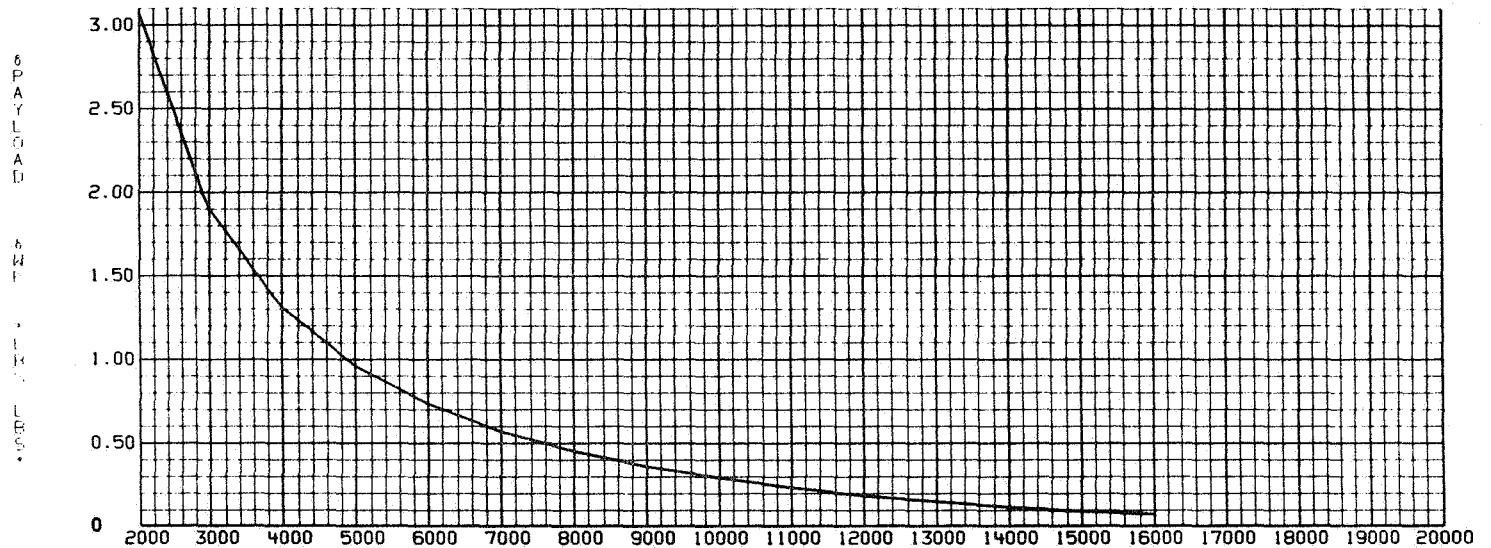


Figure 3-34

ALL FIXED POSITION WEIGHTS

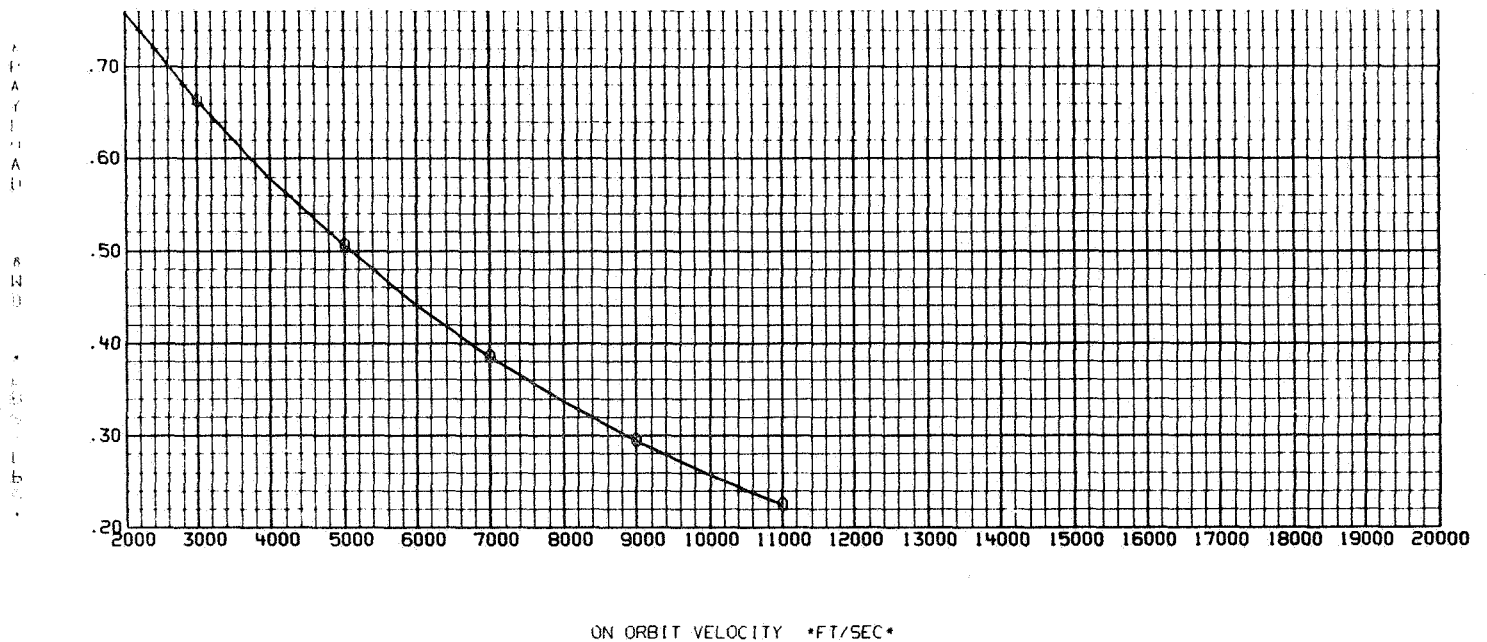
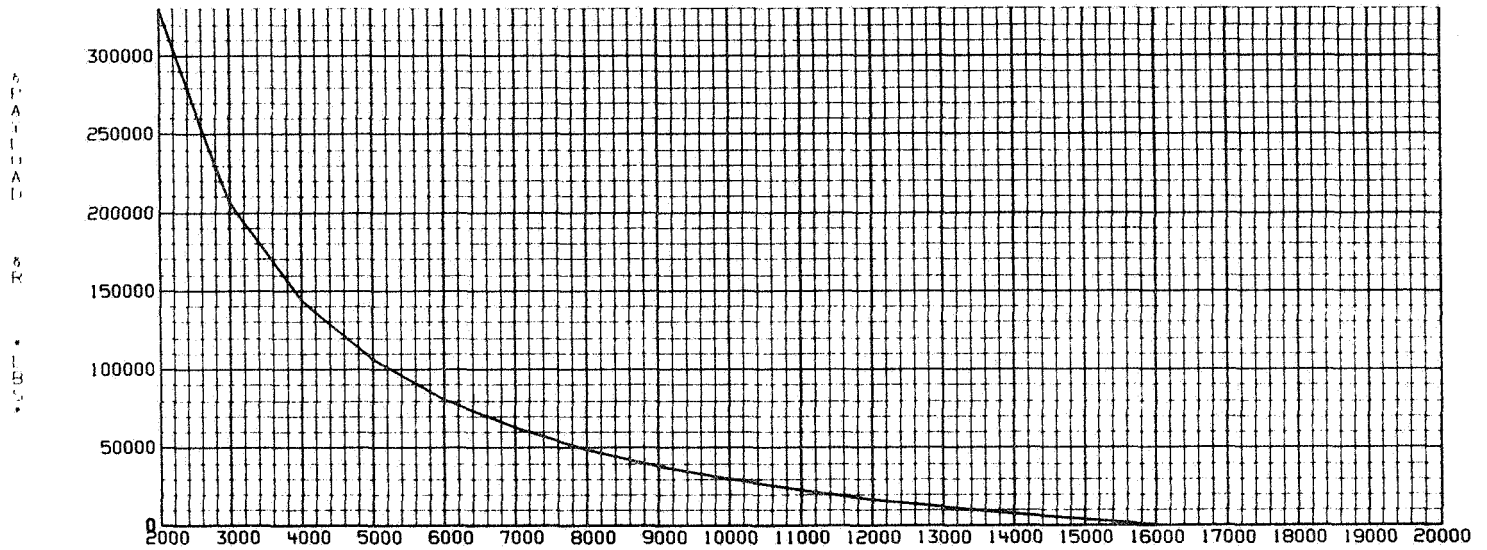


Figure 3-35

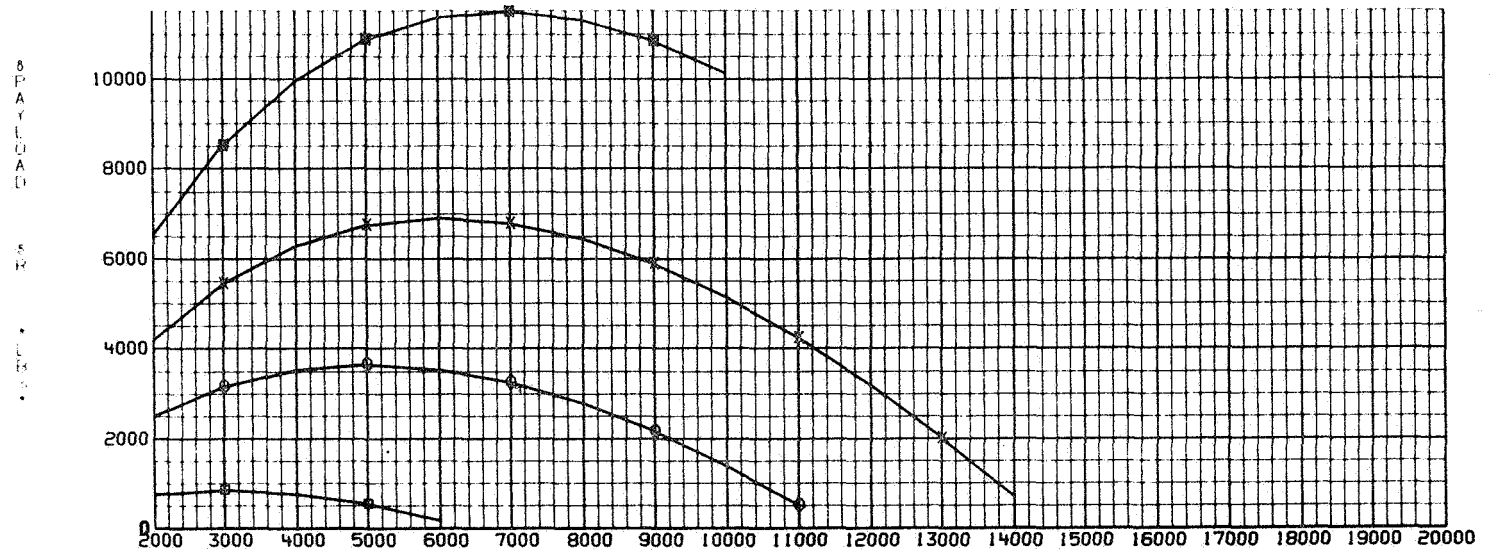
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT



O = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 □ = FIXED IGNITION 30000 LBS. * = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-36

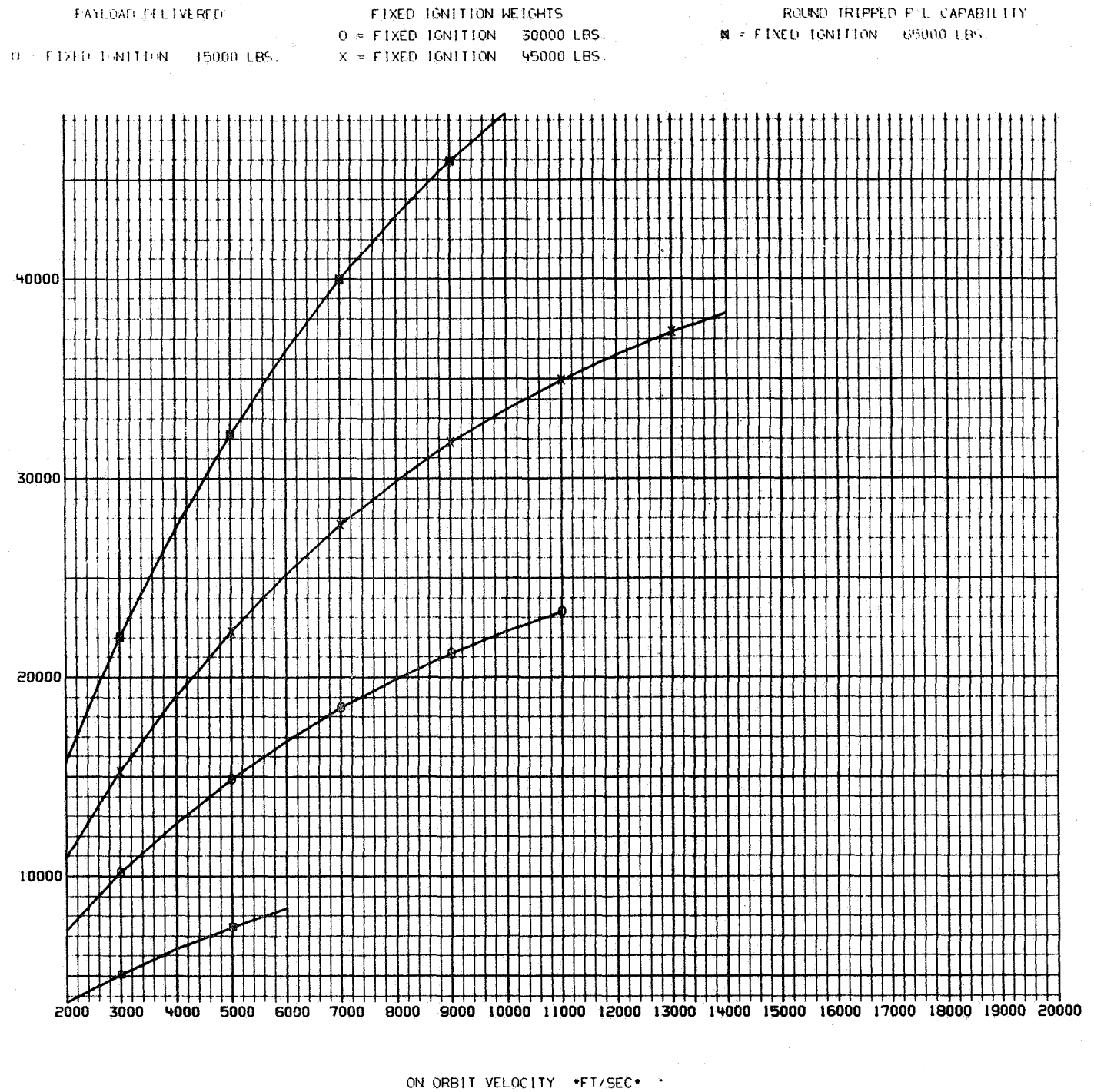


Figure 3-37

MODE 2

PAYLOAD RETURNED	50158 LBS. FIXED PROPELLANT WEIGHT	TUG - P/L RETRIEVAL CAPABILITY
• = FIXED PROPELLANT 50158 LBS.	O = FIXED IGNITION 55000 LBS.	■ = FIXED IGNITION 75000 LBS.
□ = FIXED IGNITION 45000 LBS.	X = FIXED IGNITION 65000 LBS.	

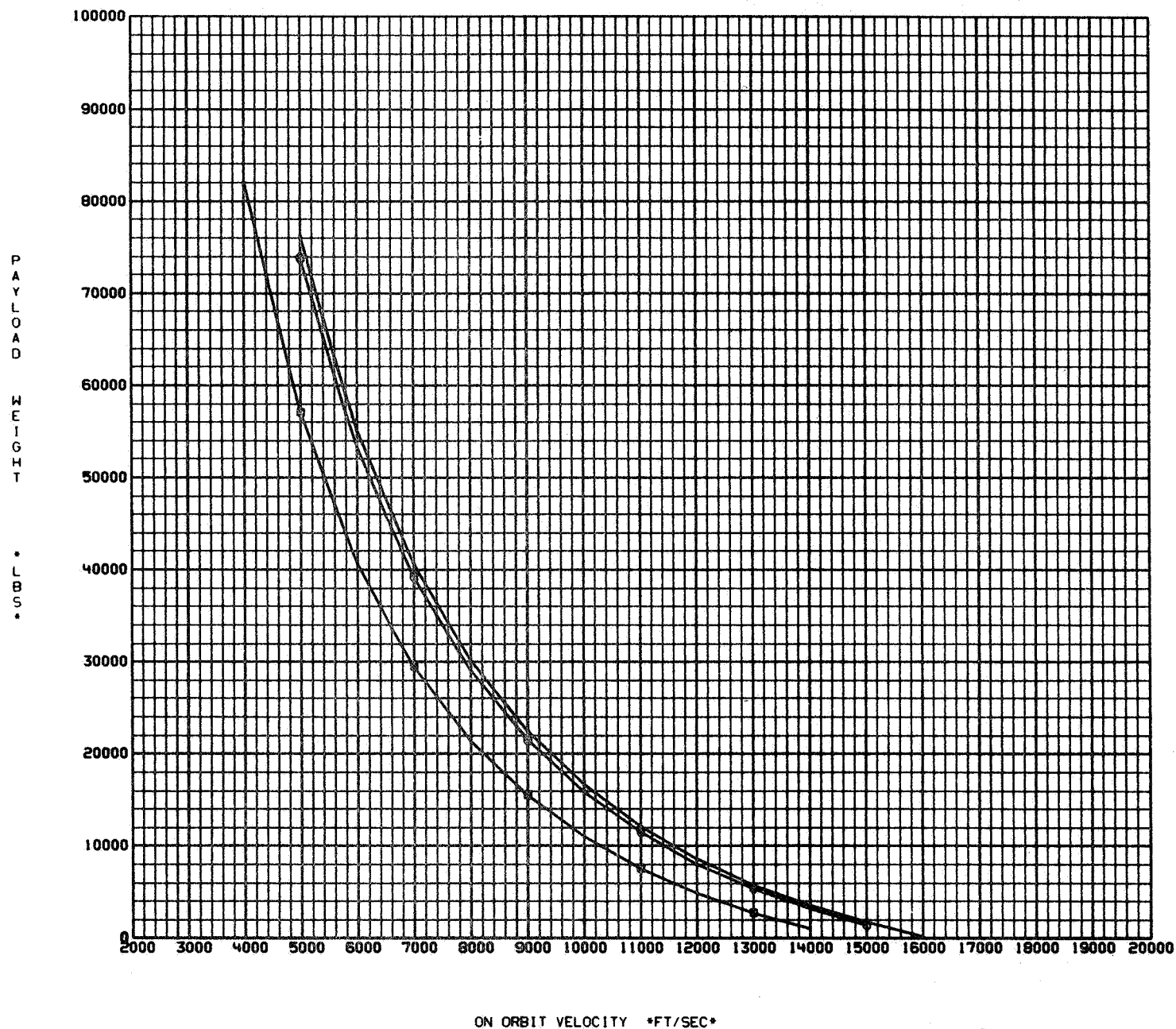


Figure 3-38

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT

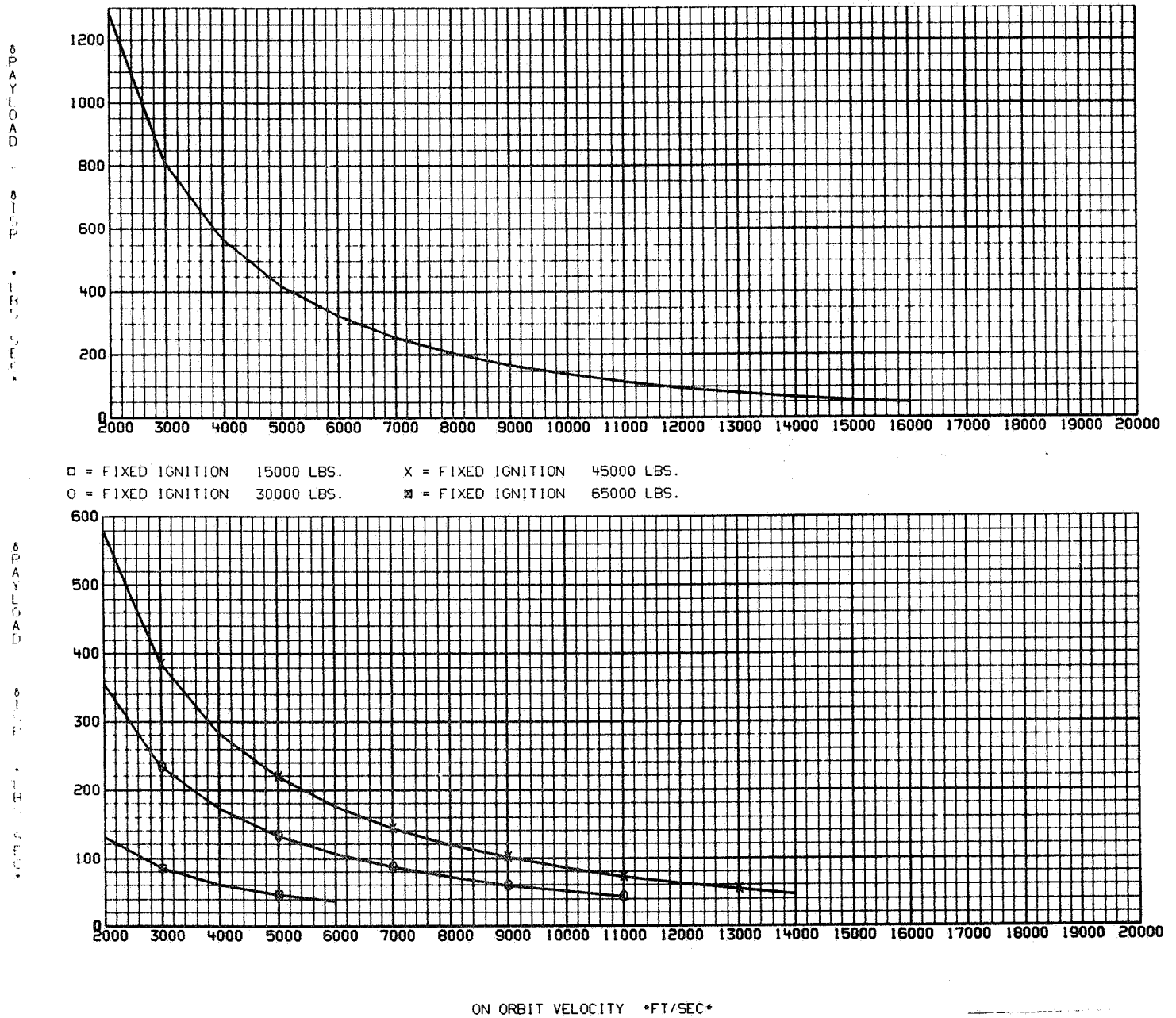
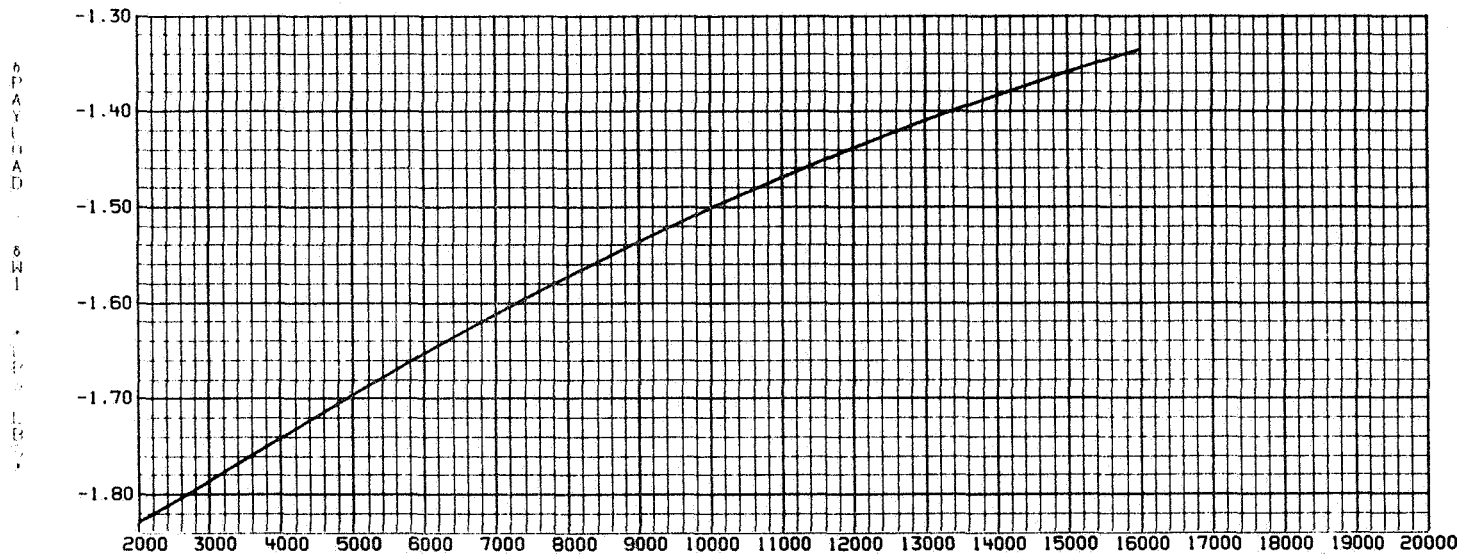


Figure 3-39

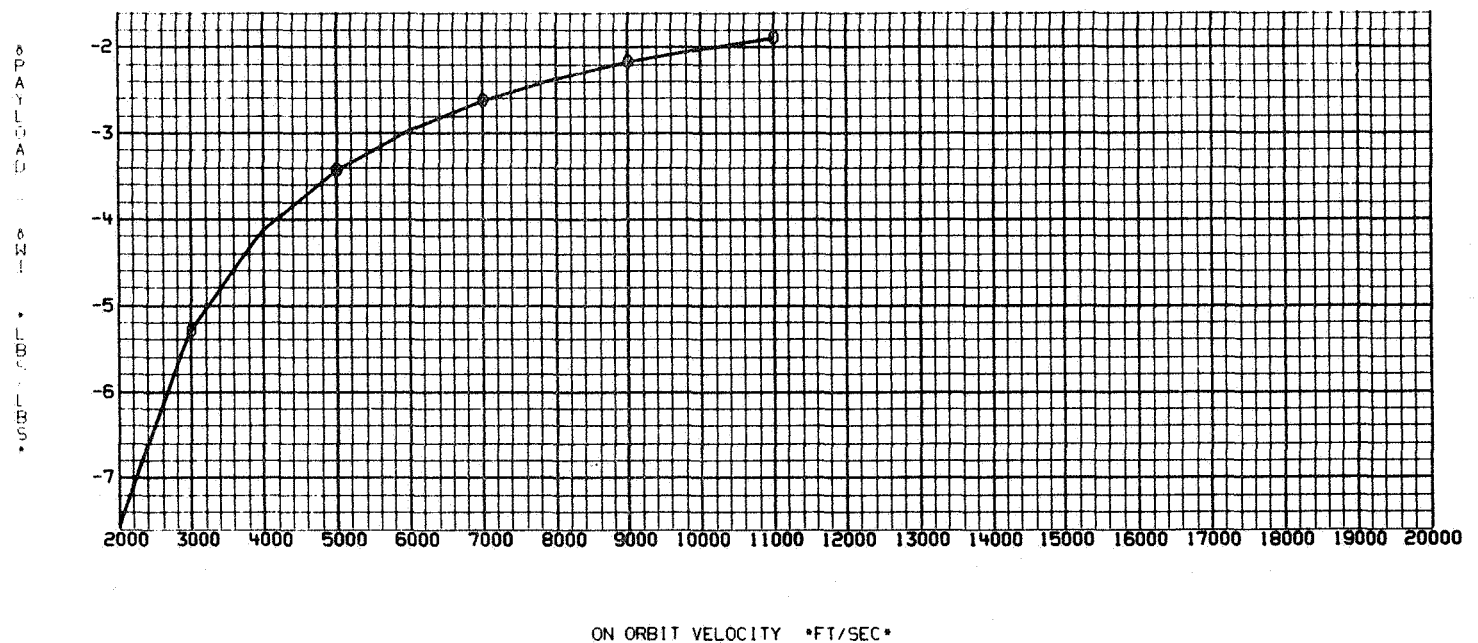
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

50150 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



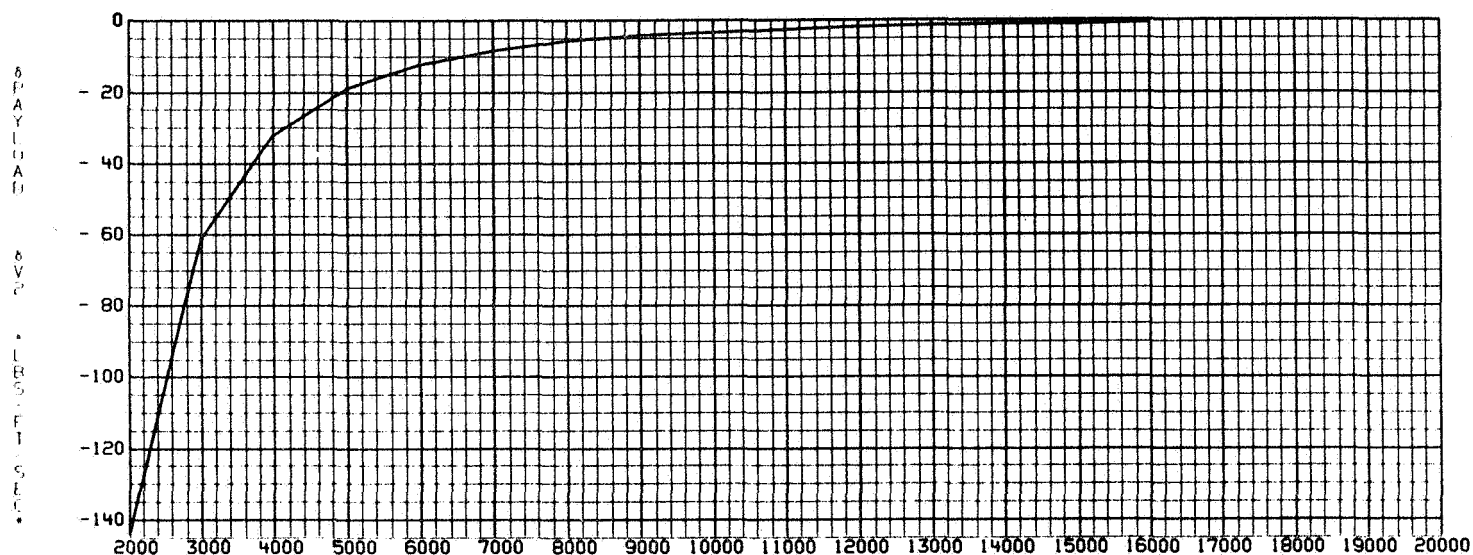
ON ORBIT VELOCITY *FT/SEC*

Figure 3-40

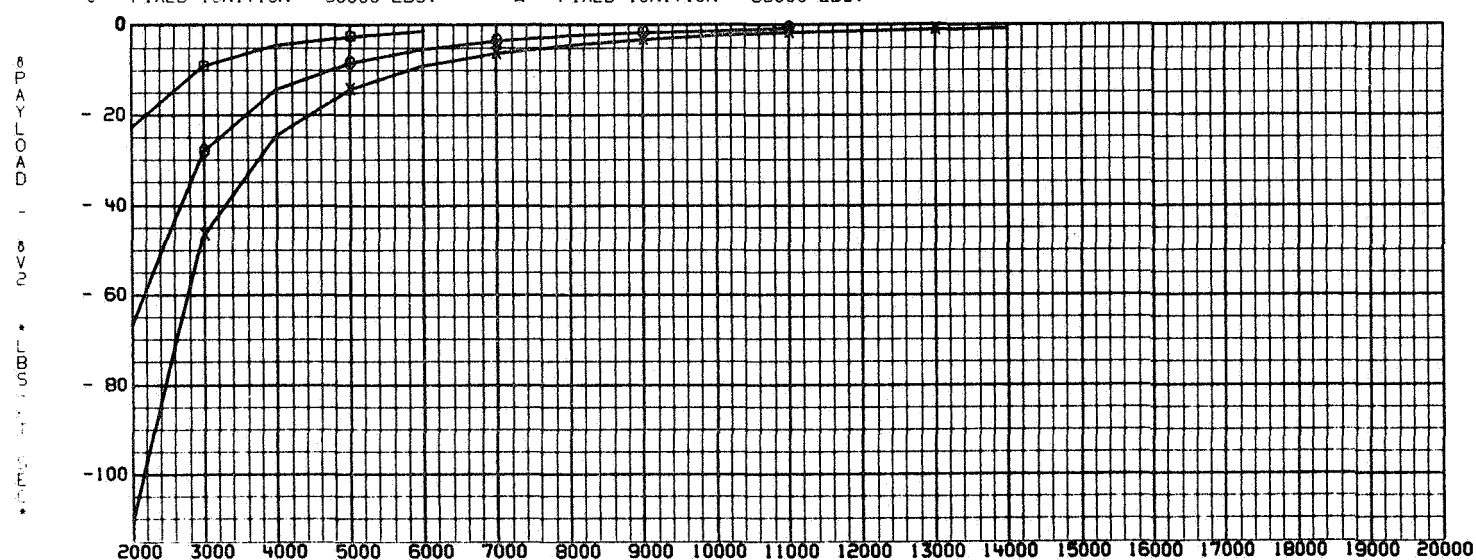
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-41

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

50158 LBS. FIXED PROPELLANT WEIGHT

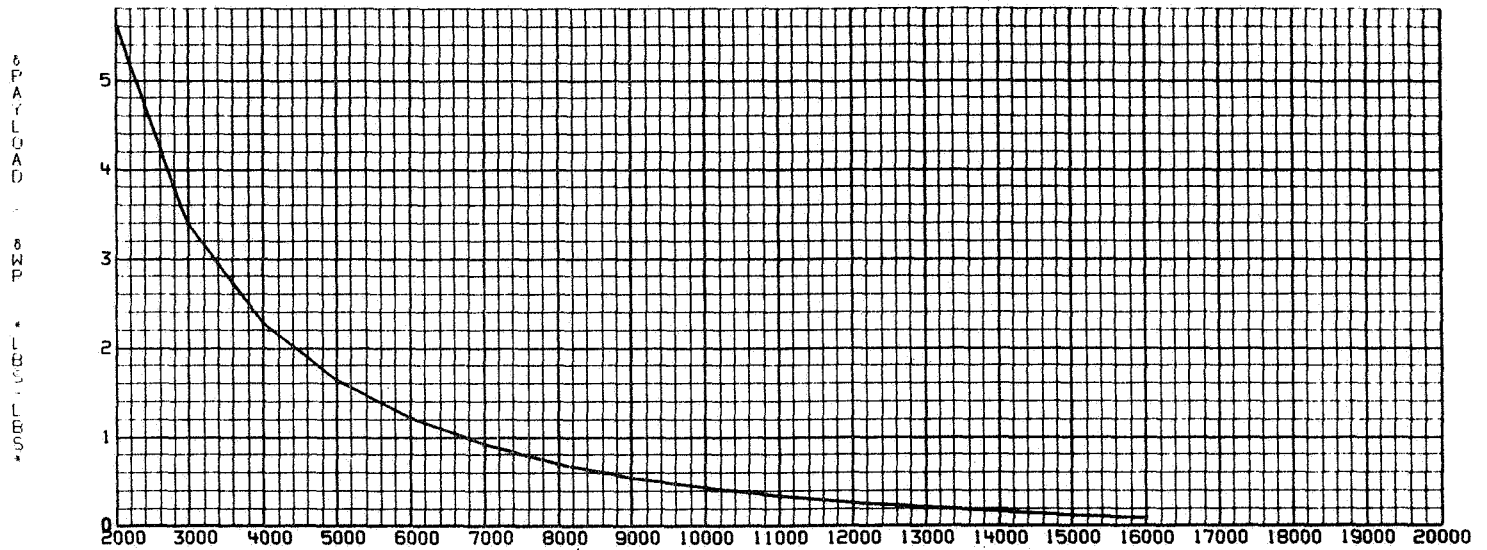


Figure 3-42

ALL FIXED IGNITION WEIGHTS

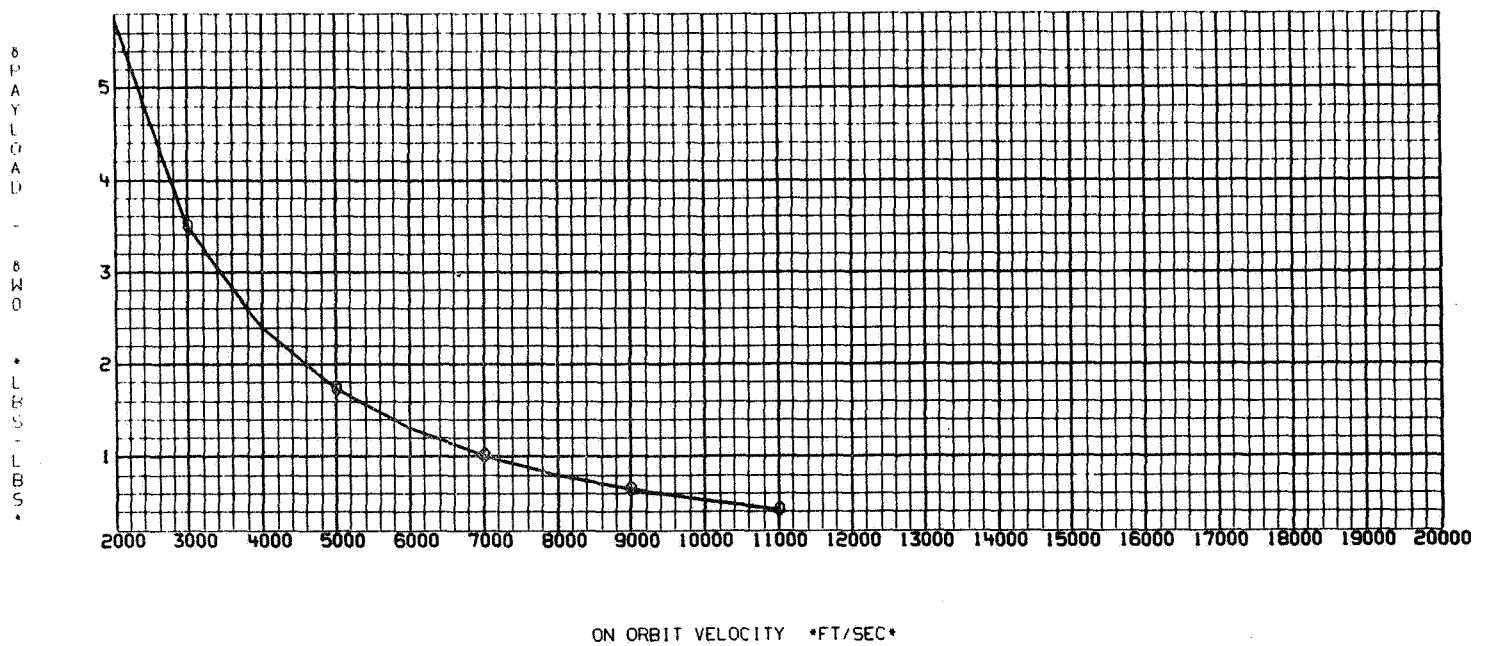


Figure 3-43

NOTE

Offloaded propellant
in Mode 2 is not
a function of ΔV

Figure 3-44

MODE 3

PAYLOAD DELIVERED
 . = FIXED PROPELLANT 50158 LBS.
 O = FIXED IGNITION 15000 LBS.

50158 LBS. FIXED PROPELLANT WEIGHT
 O = FIXED IGNITION 30000 LBS.
 X = FIXED IGNITION 45000 LBS.

EXPENDABLE P/L ** REUSEABLE TUG
 ■ = FIXED IGNITION 65000 LBS.

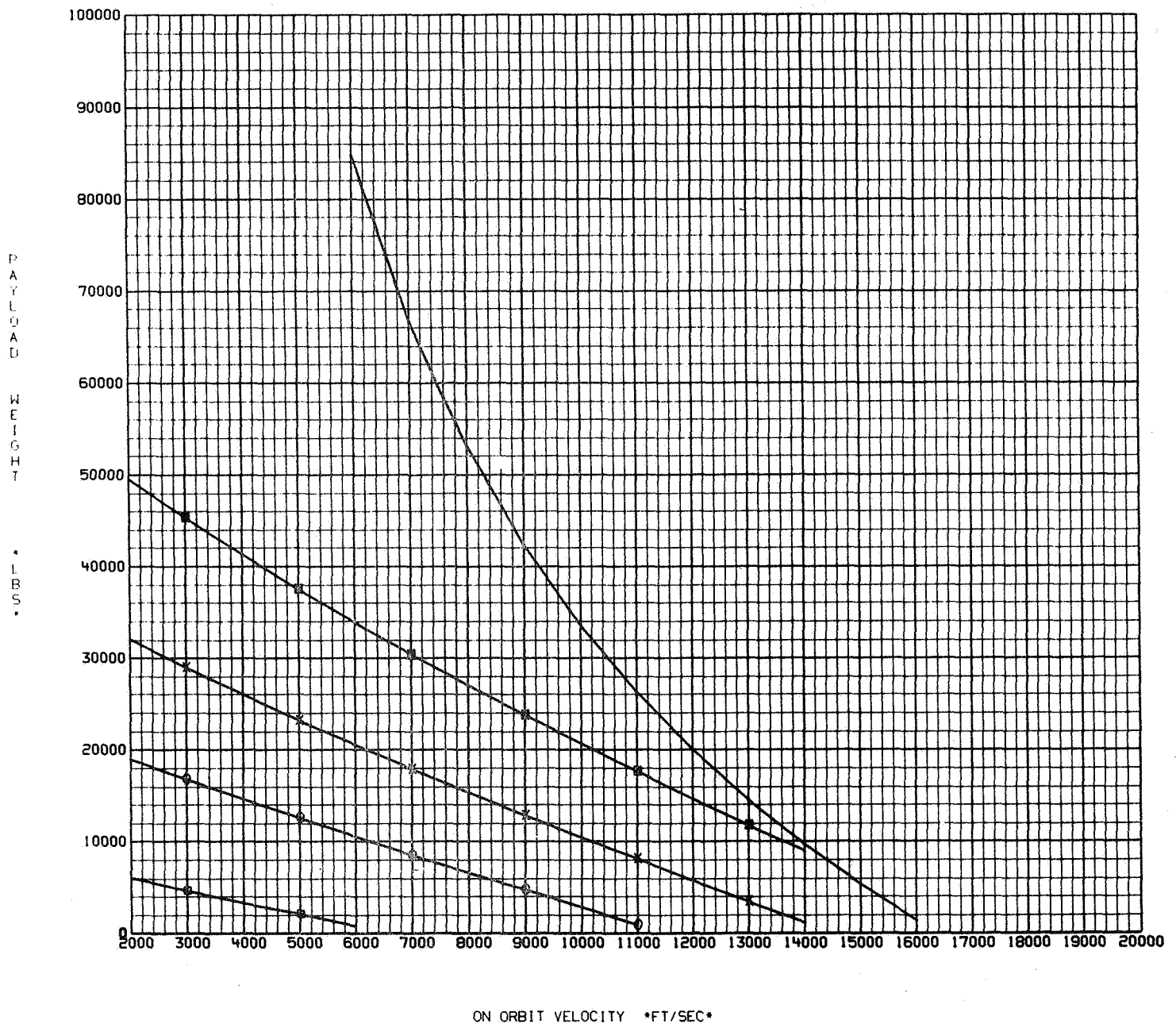
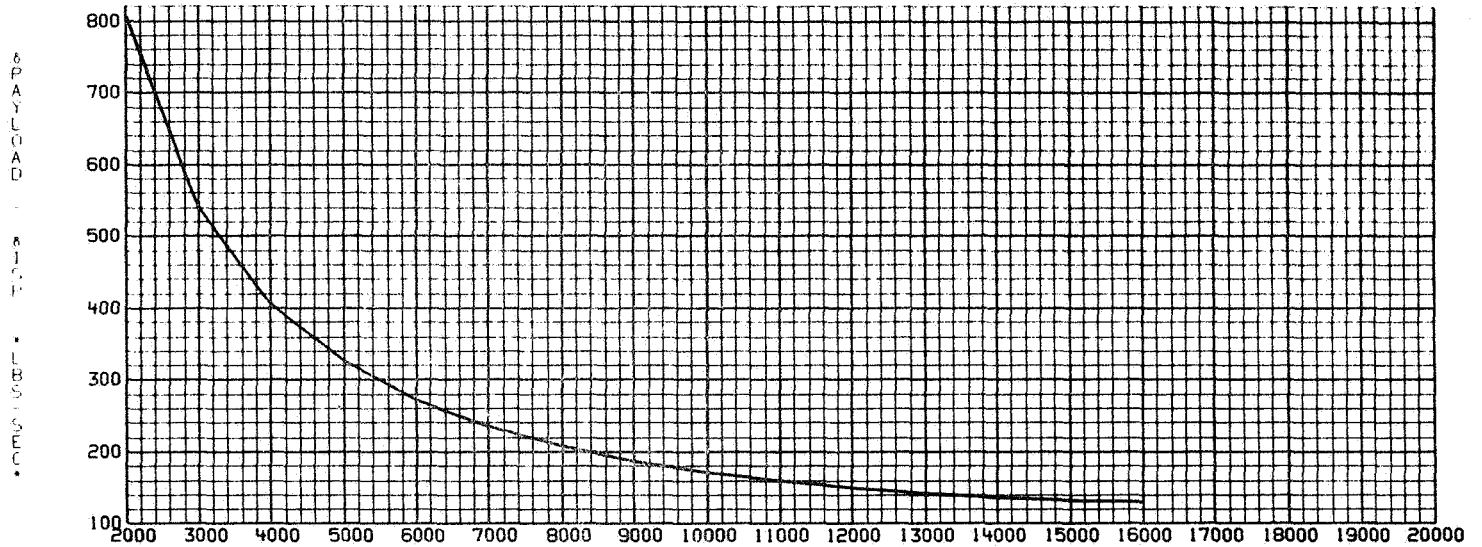


Figure 3-45

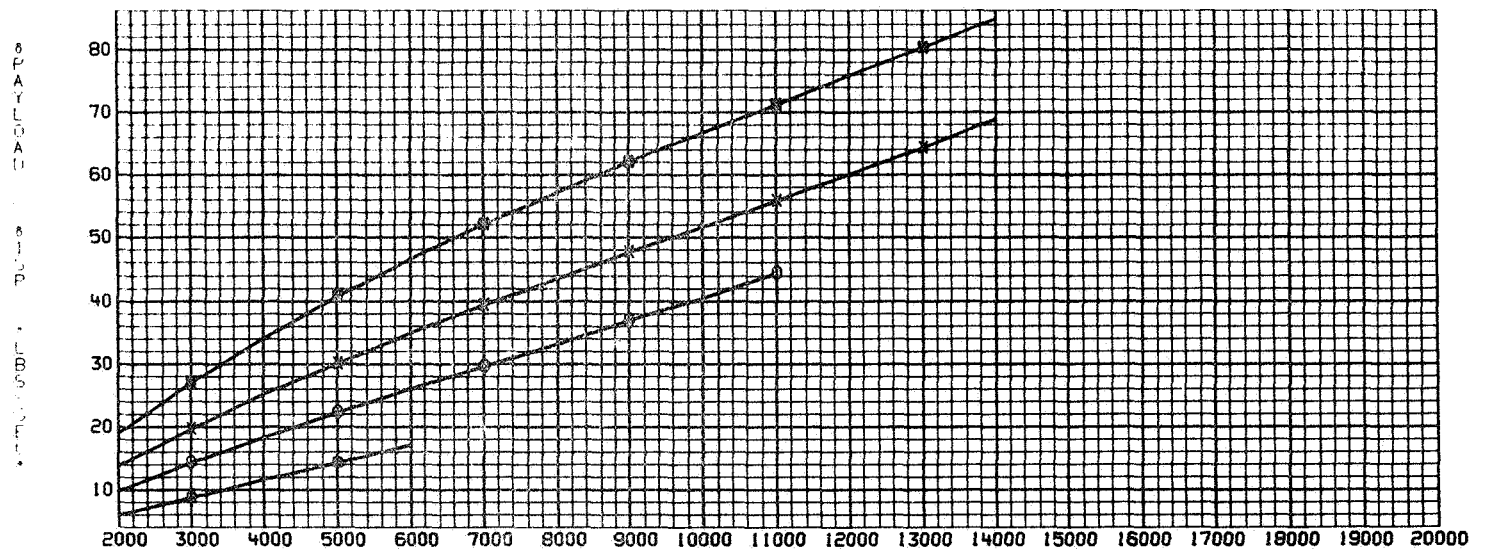
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

50158 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



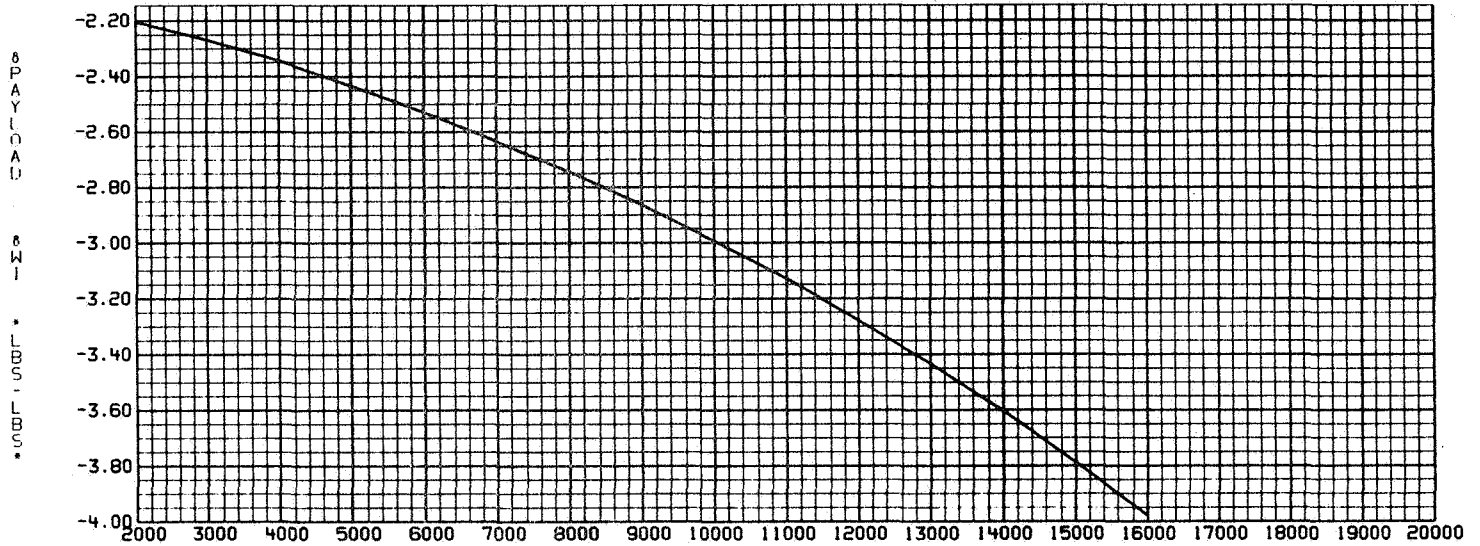
ON ORBIT VELOCITY *FT/SEC*

Figure 3-46

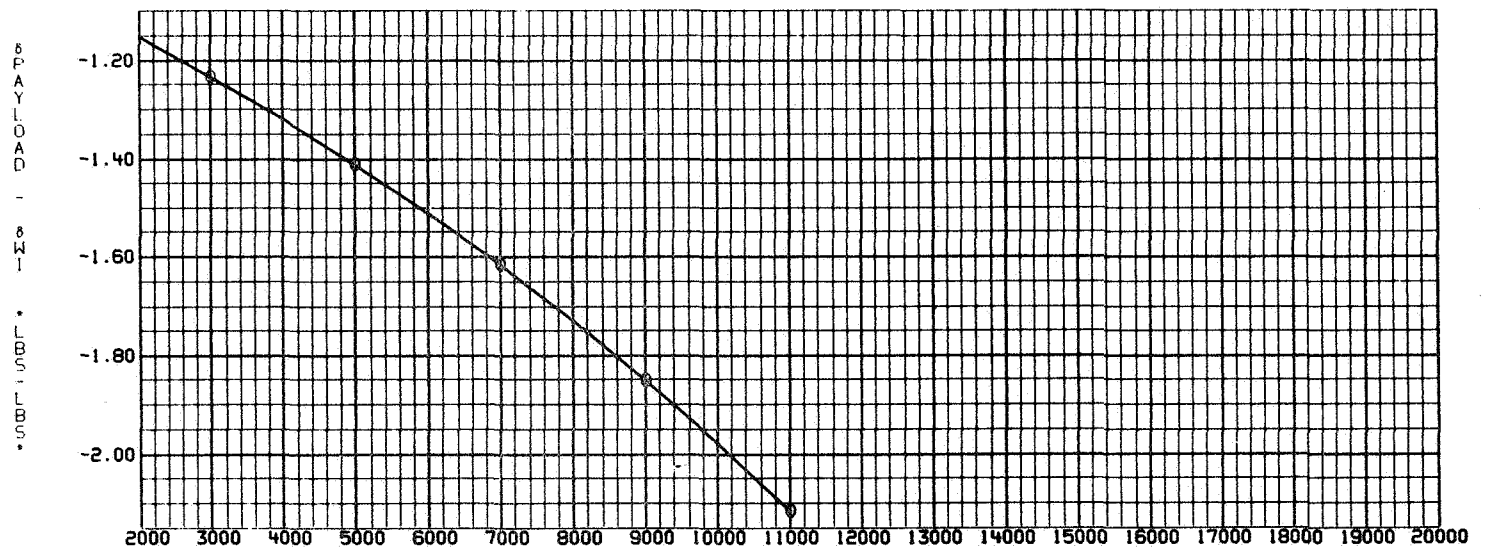
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

50158 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



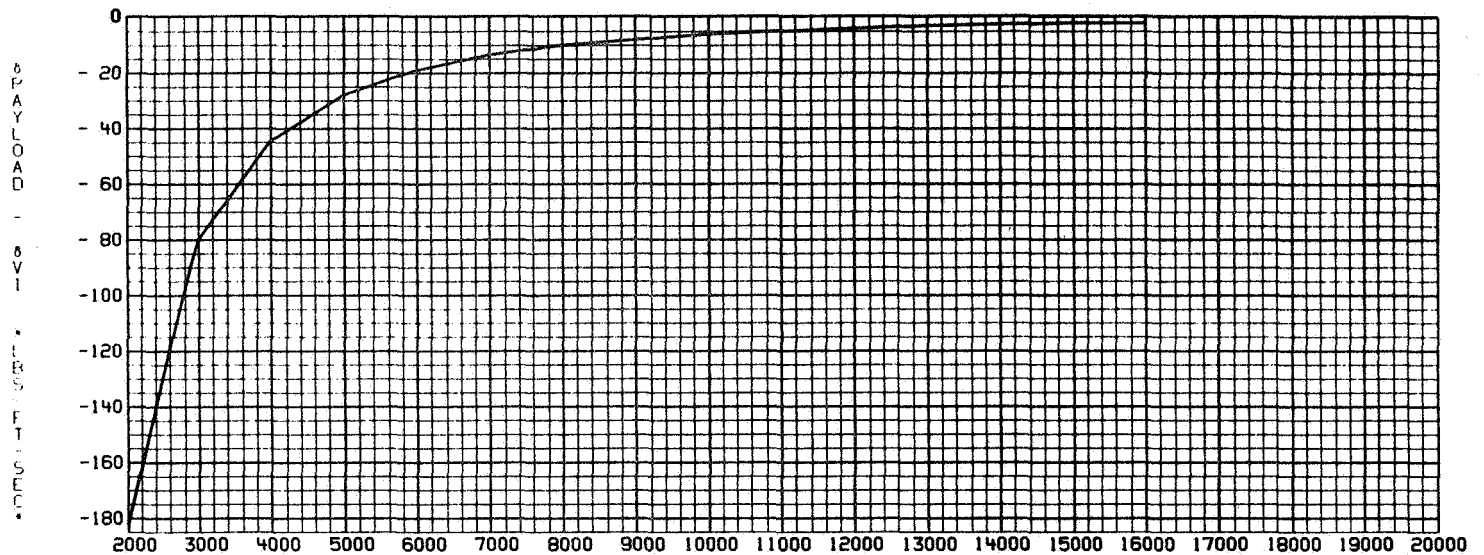
ON ORBIT VELOCITY *FT/SEC*

Figure 3-47

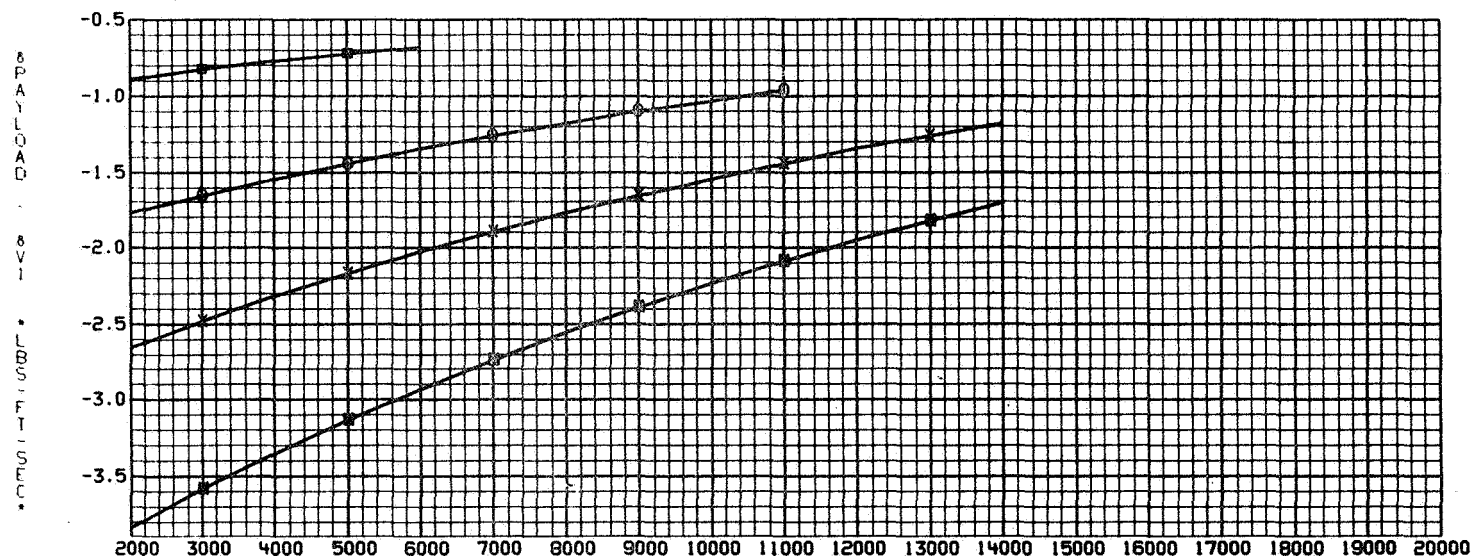
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

50158 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-48

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSABLE TUG

50158 LBS. FIXED PROPELLANT WEIGHT

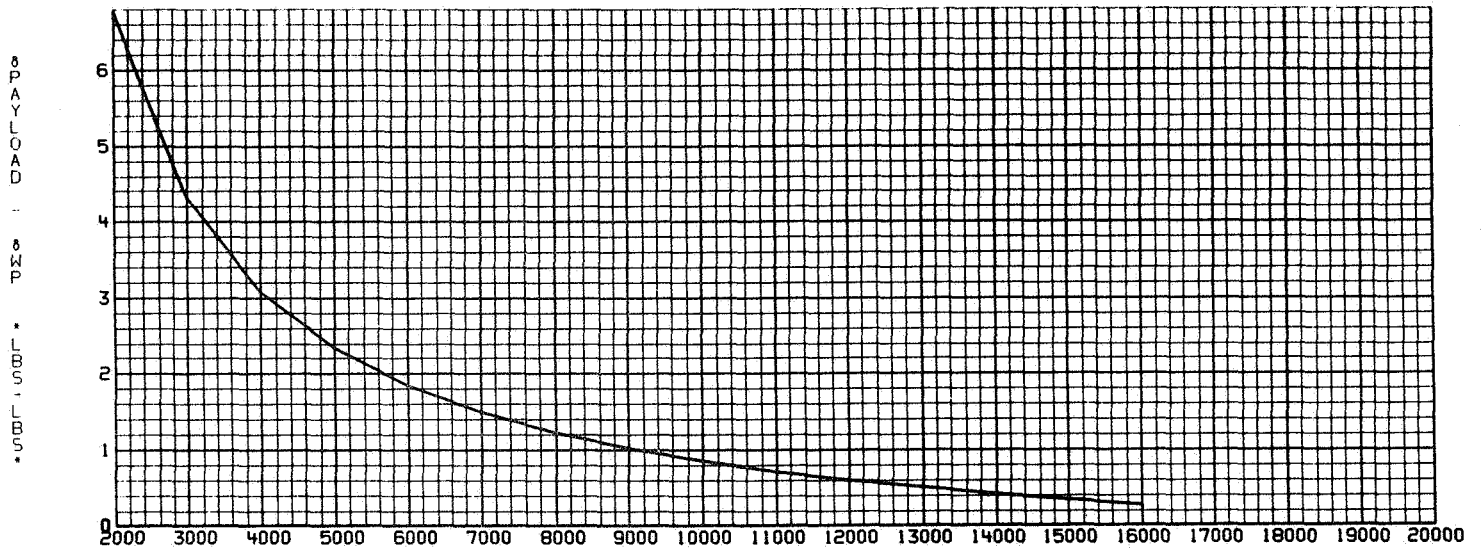


Figure 3-49

ALL FIXED IGNITION WEIGHTS

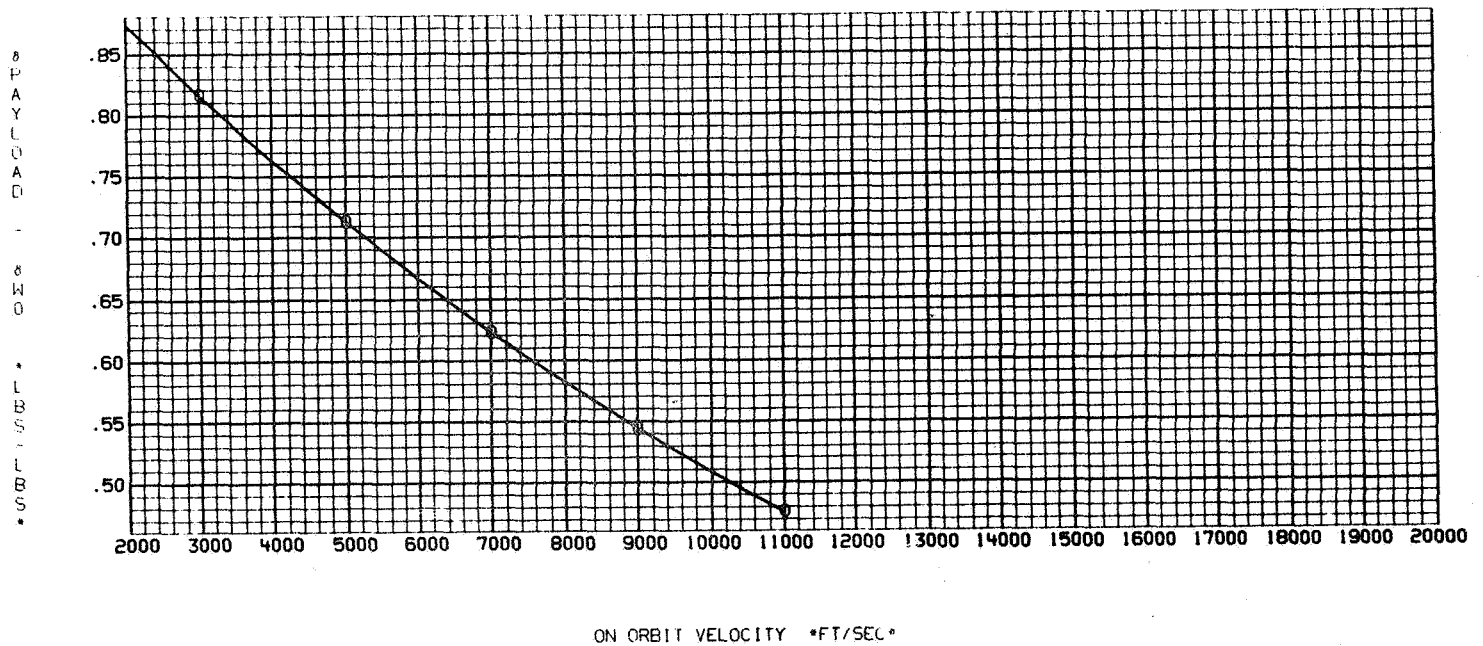


Figure 3-50

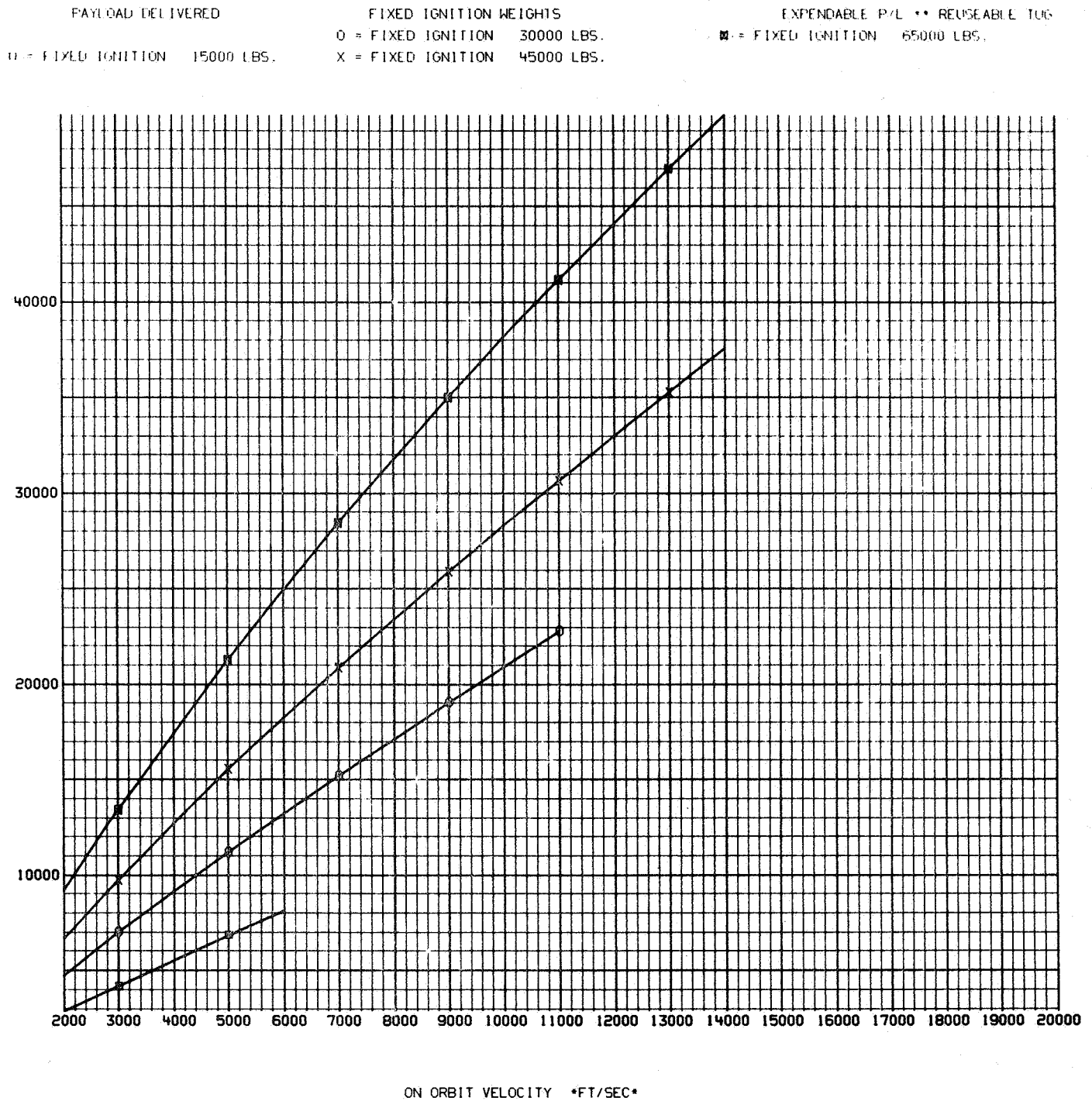


Figure 3-51

MODE 4

PAYLOAD DELIVERED
 * = FIXED PROPELLANT 50158 LBS.
 □ = FIXED IGNITION 15000 LBS.

50158 LBS. FIXED PROPELLANT WEIGHT
 O = FIXED IGNITION 30000 LBS.
 X = FIXED IGNITION 45000 LBS.

EXPENDABLE TUG AND P/L
 * = FIXED IGNITION 65000 LBS.

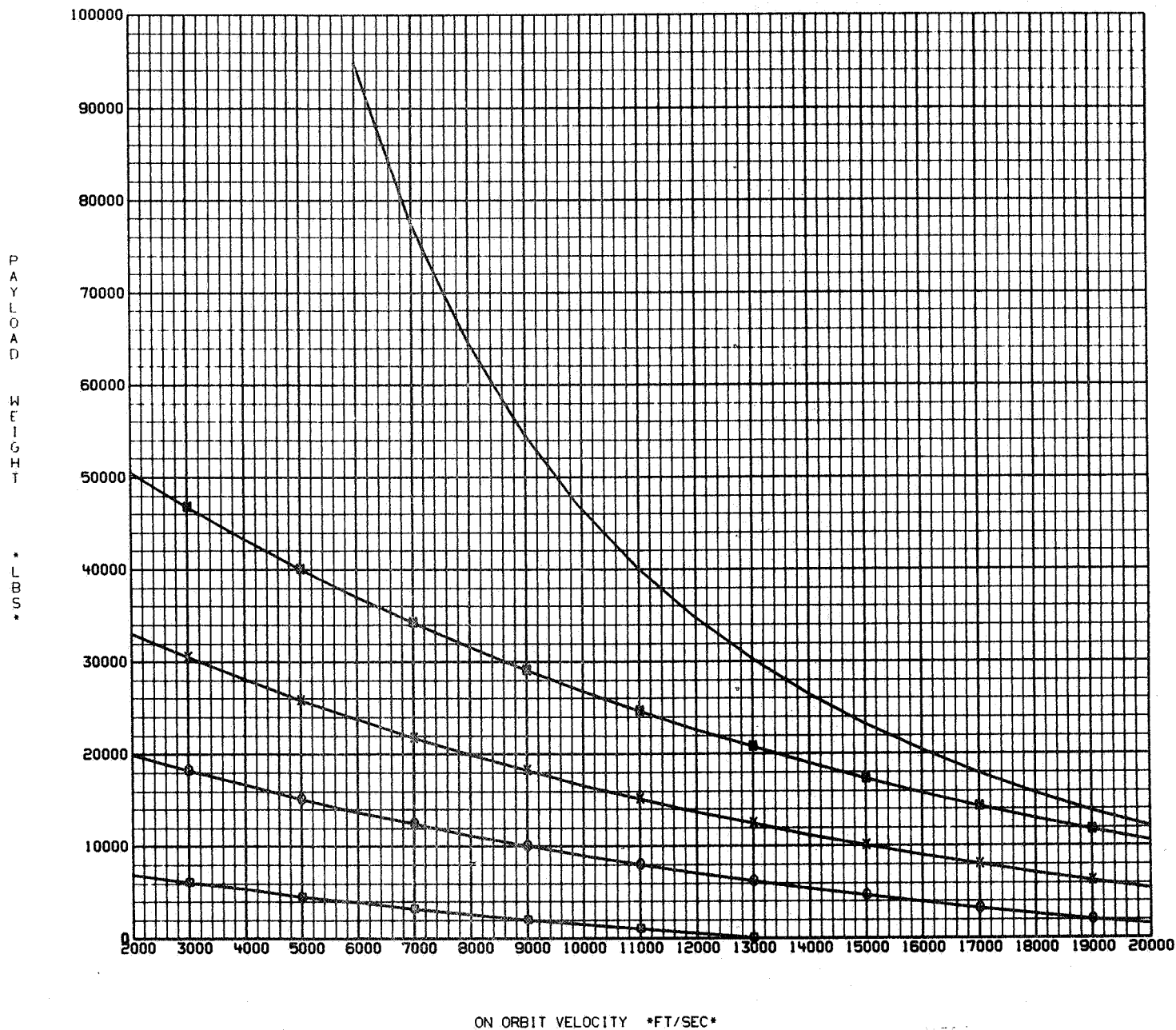
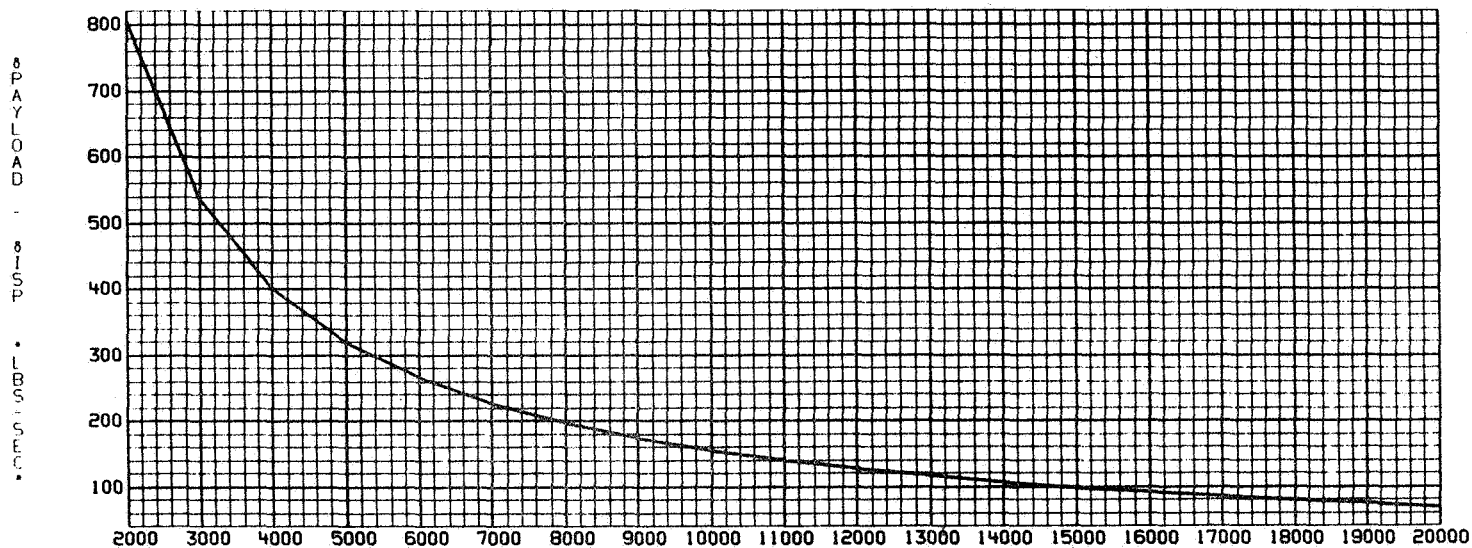


Figure 3-52

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.

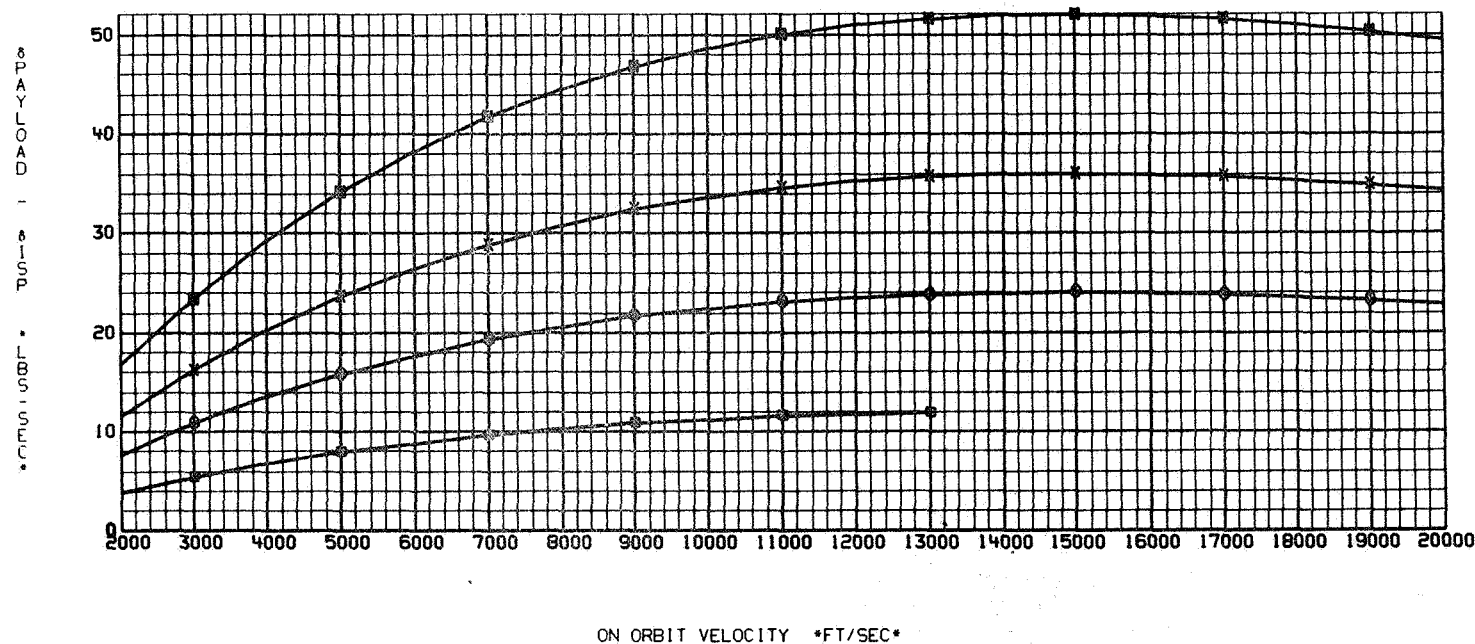
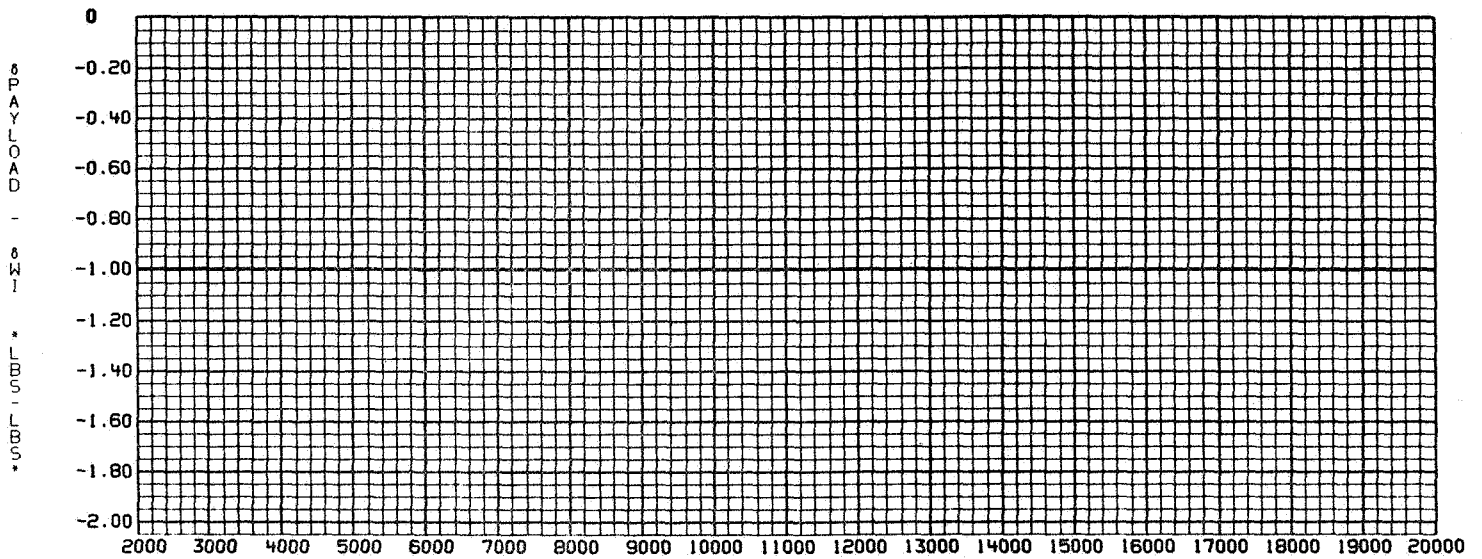


Figure 3-53

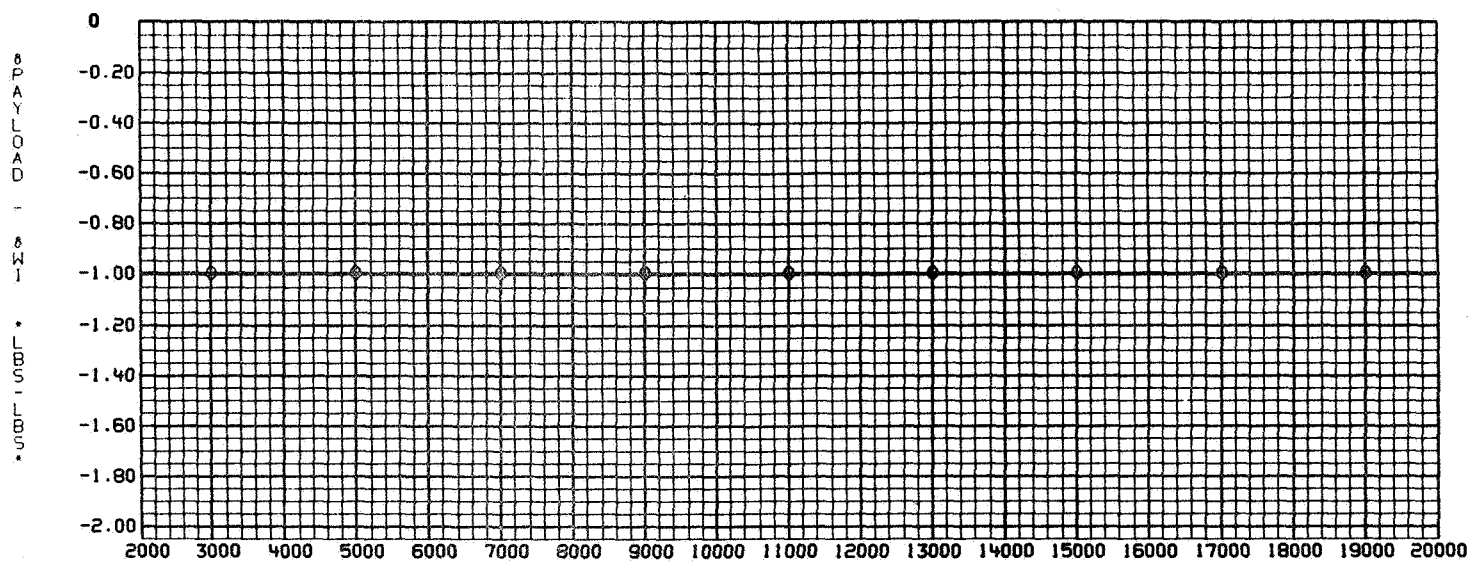
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



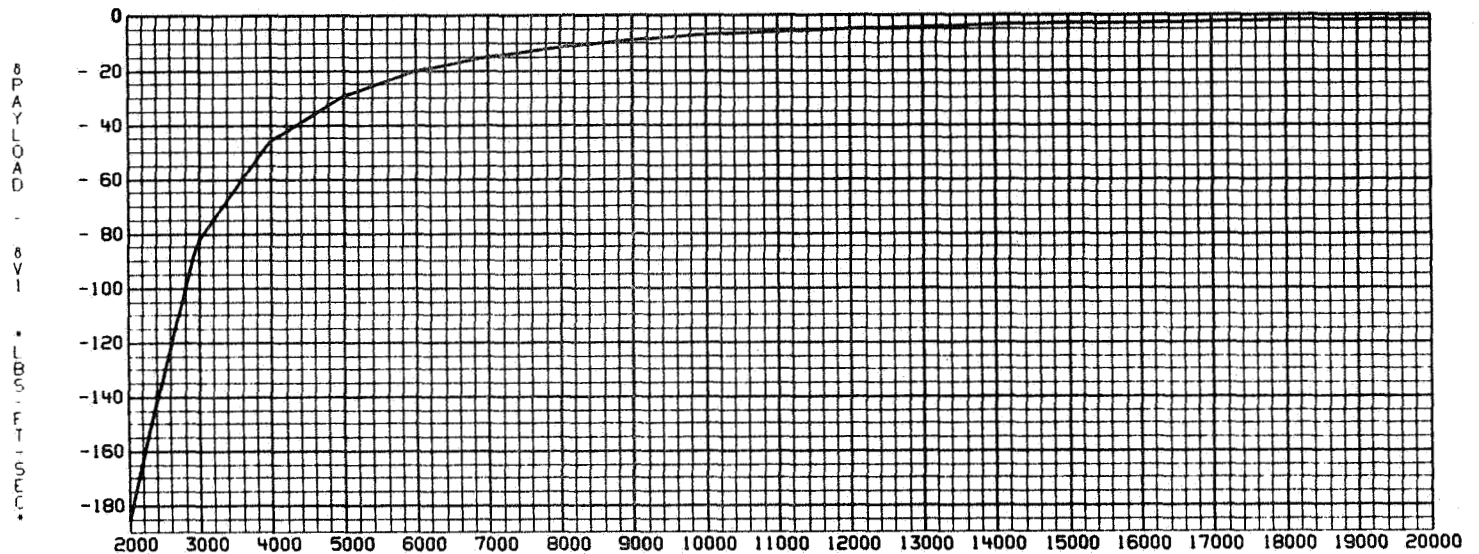
ON ORBIT VELOCITY *FT/SEC*

Figure 3-54

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. * = FIXED IGNITION 65000 LBS.

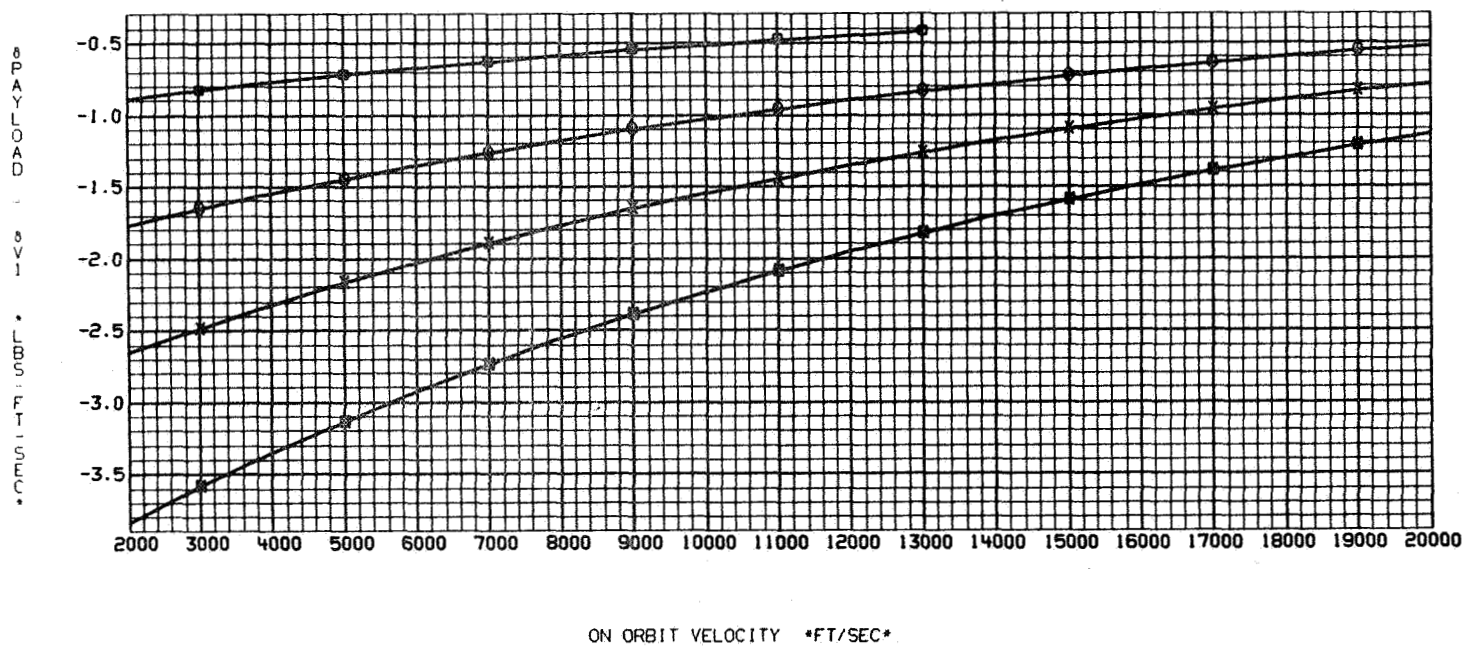


Figure 3-55

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

50158 LBS. FIXED PROPELLANT WEIGHT

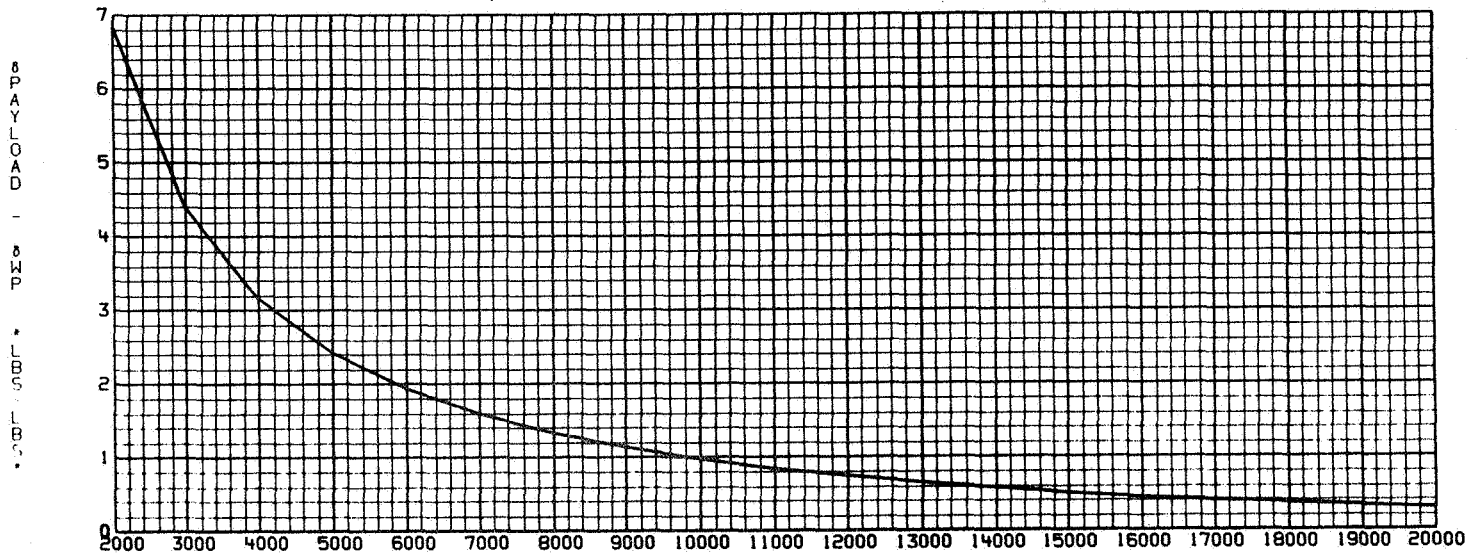


Figure 3-56

ALL FIXED IGNITION HEIGHTS

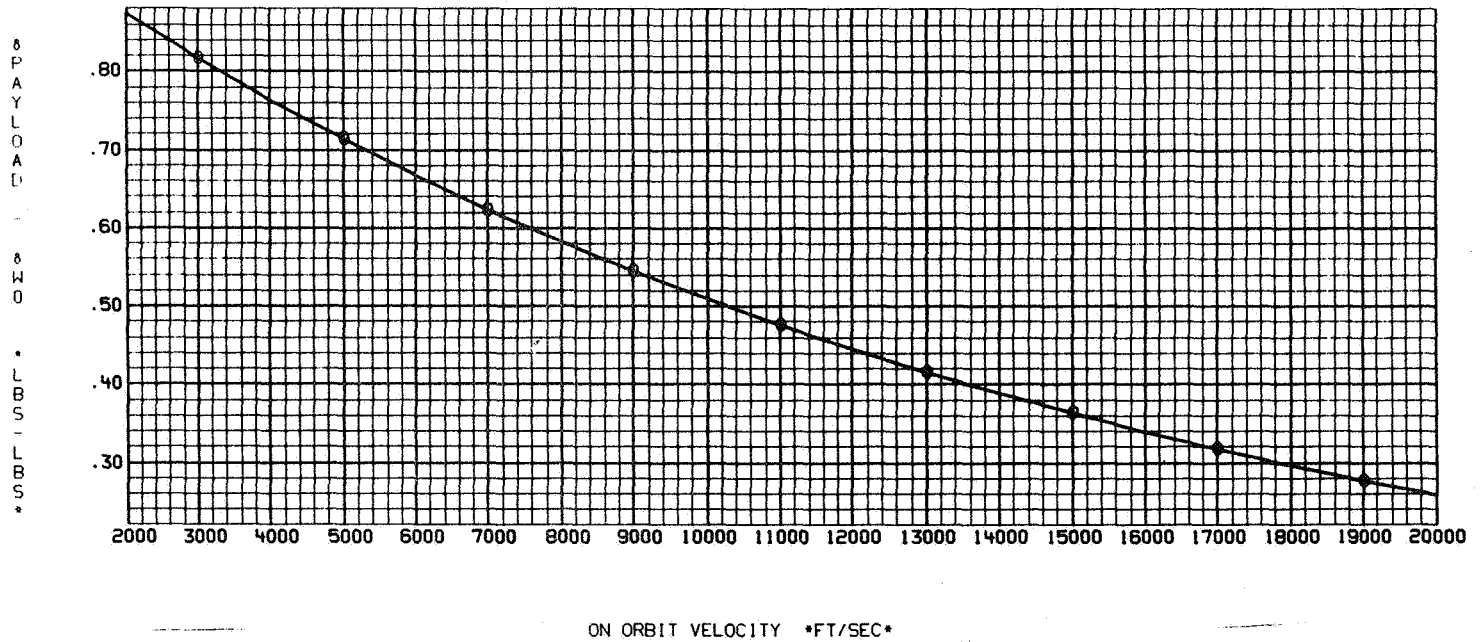


Figure 3-57

PAYLOAD DELIVERED
 □ = FIXED IGNITION 15000 LBS.
 ○ = FIXED IGNITION 30000 LBS.
 X = FIXED IGNITION 45000 LBS.
 ■ = EXPENDABLE TUG AND P.L. 65000 LBS.

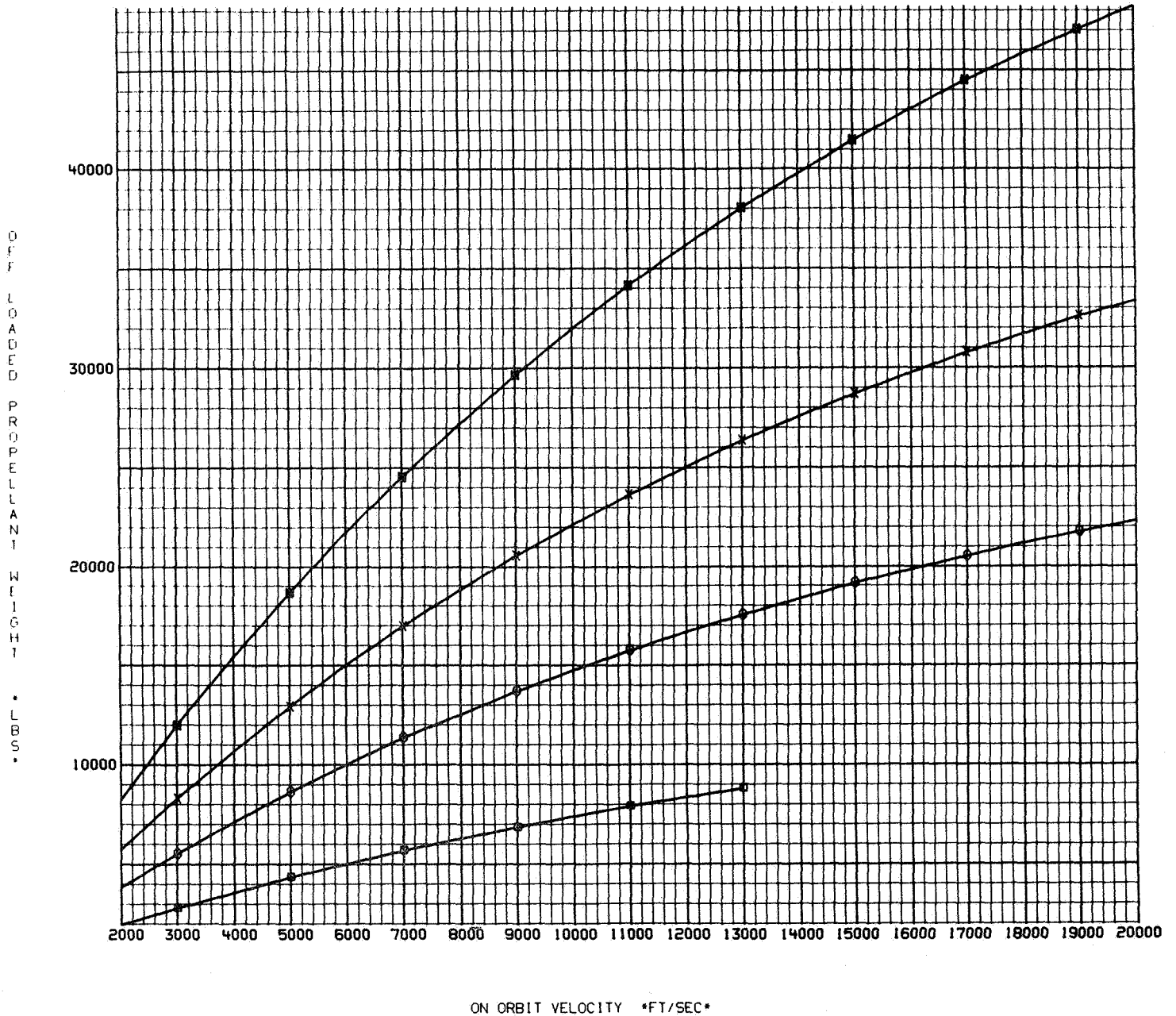


Figure 3-58

MODE 1

PAYLOAD DELIVERED	36295 LBS. FIXED PROPELLANT WEIGHT	ROUND TRIPPED P/L CAPABILITY
• = FIXED PROPELLANT 36295 LBS.	O = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.	

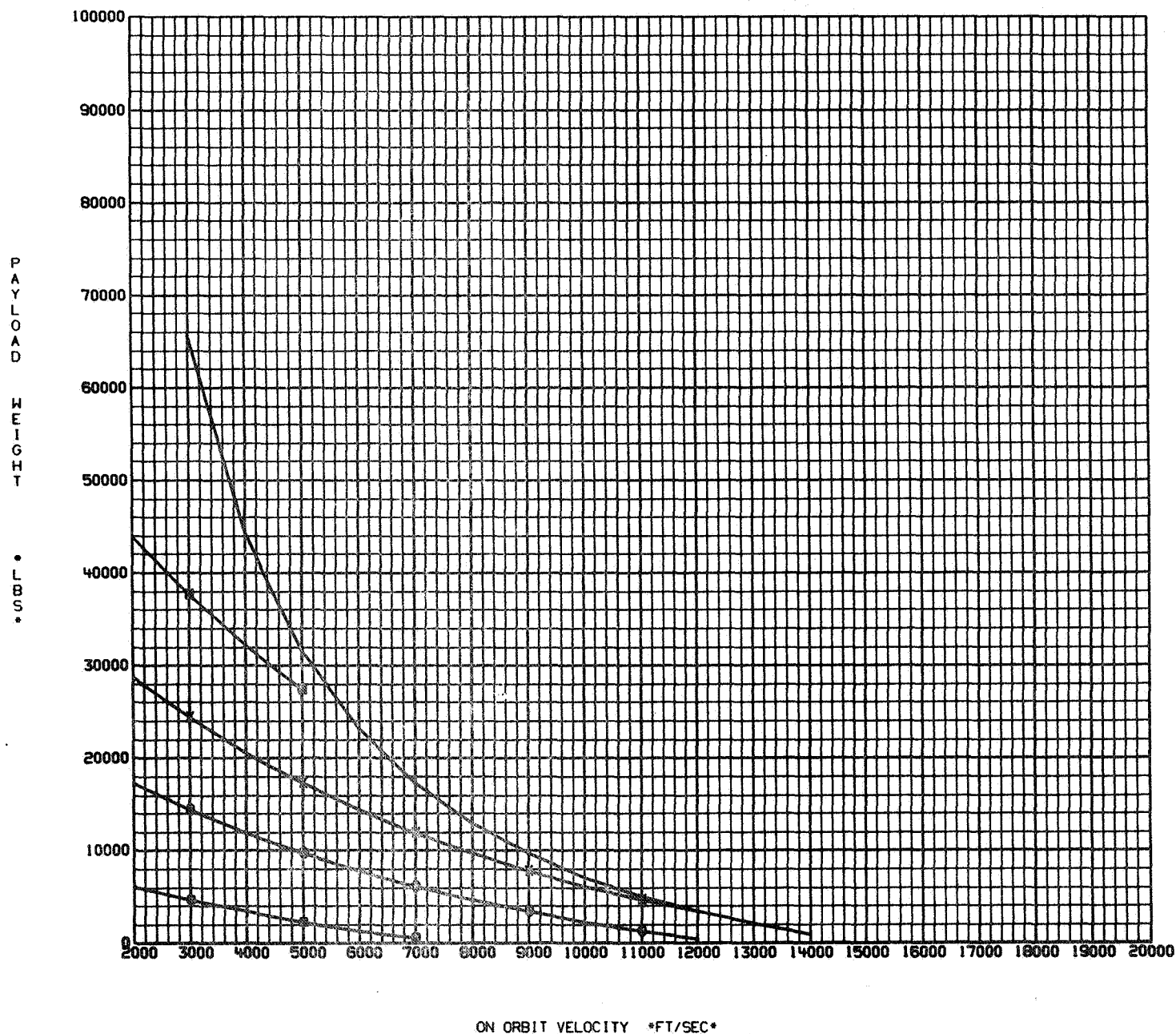


Figure 3-59

PAYLOAD DELIVERED
36295 LBS. FIXED PROPELLANT WEIGHT
ROUND TRIPPED P/L CAPABILITY

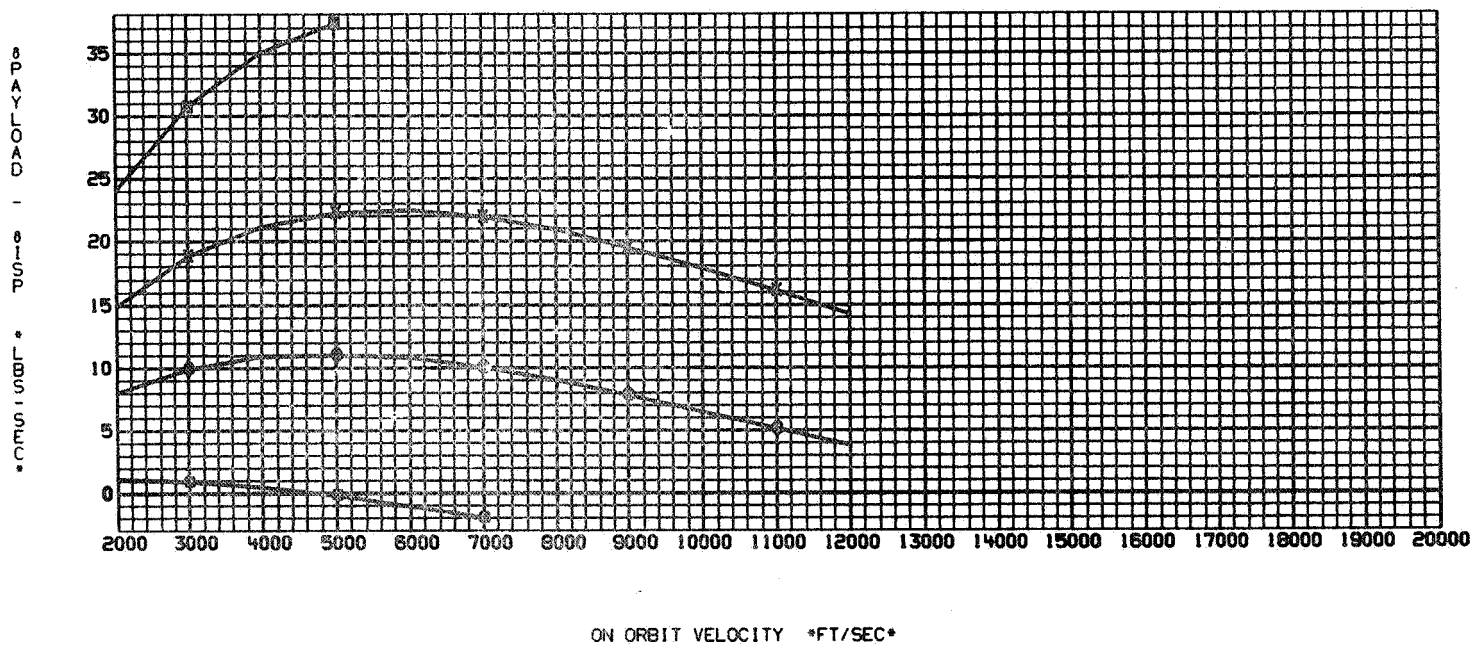
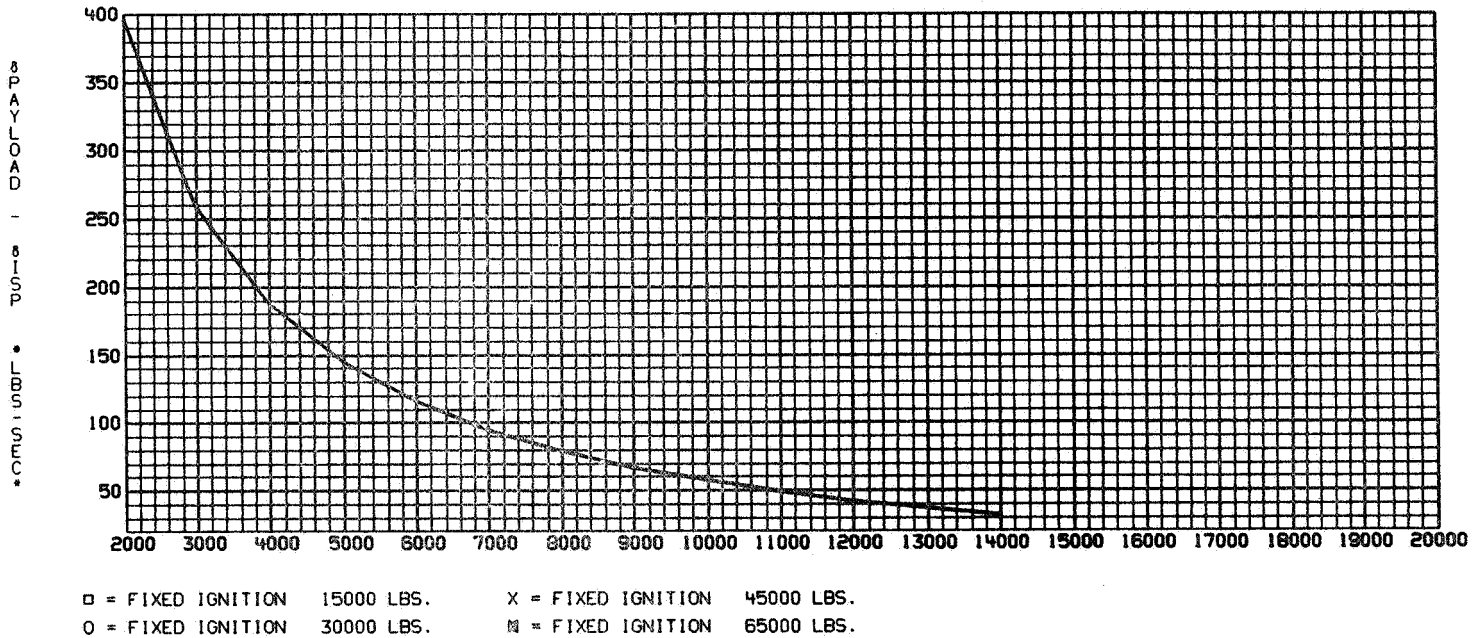
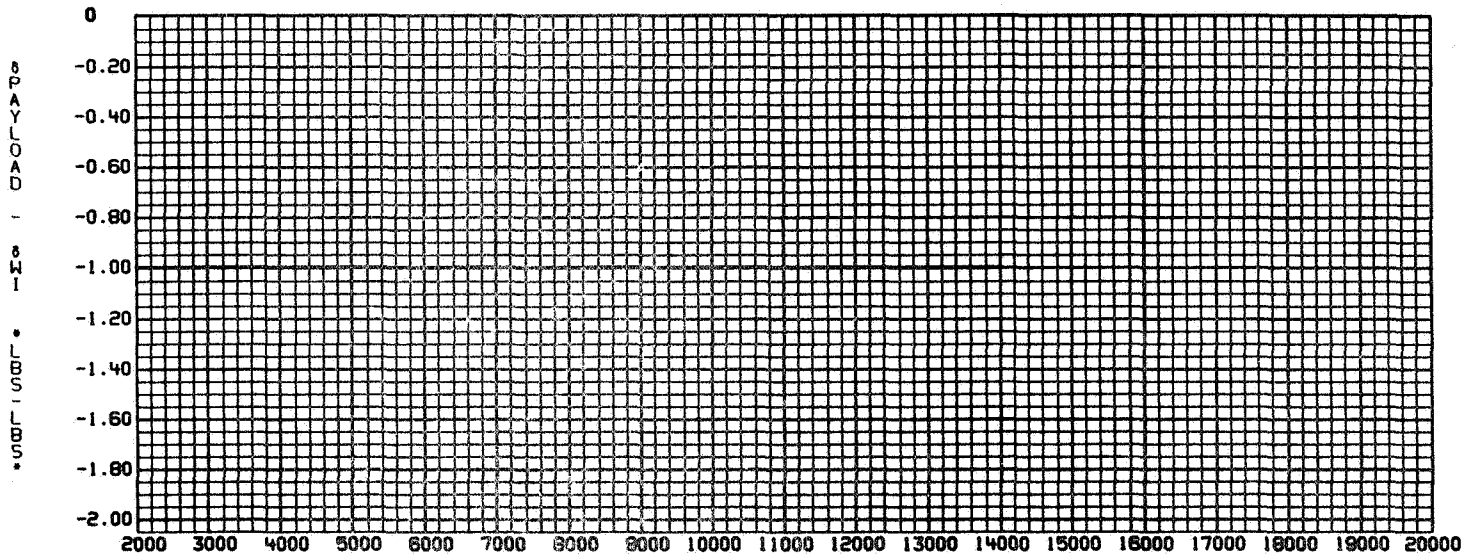


Figure 3-60

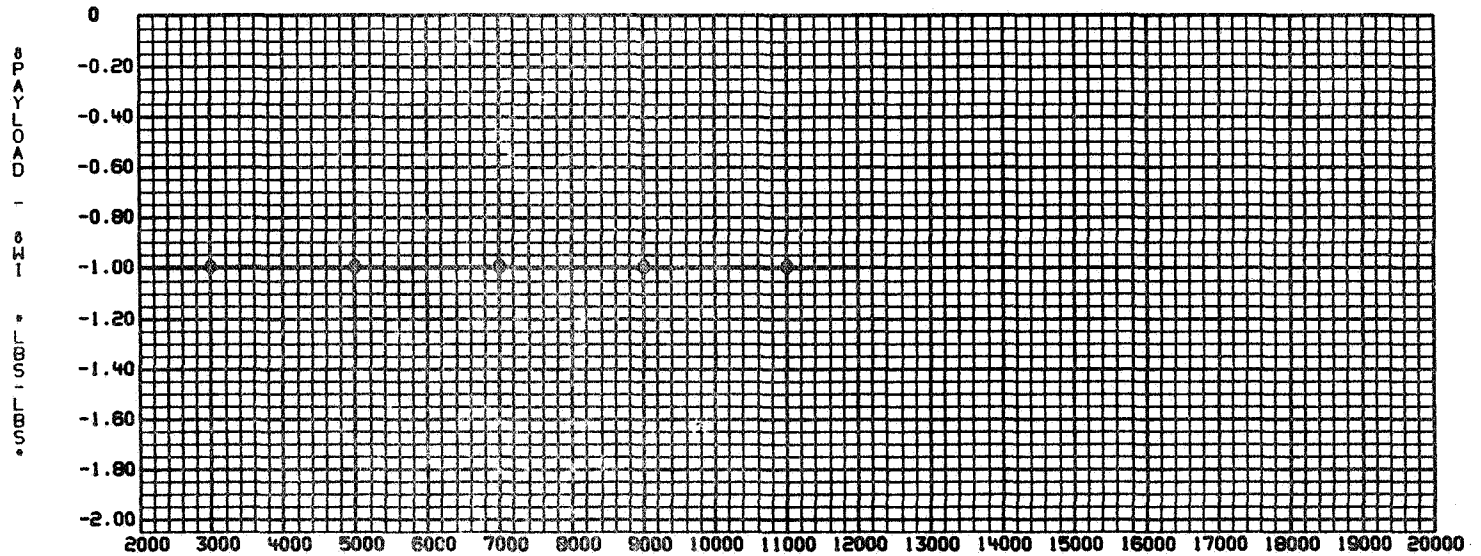
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



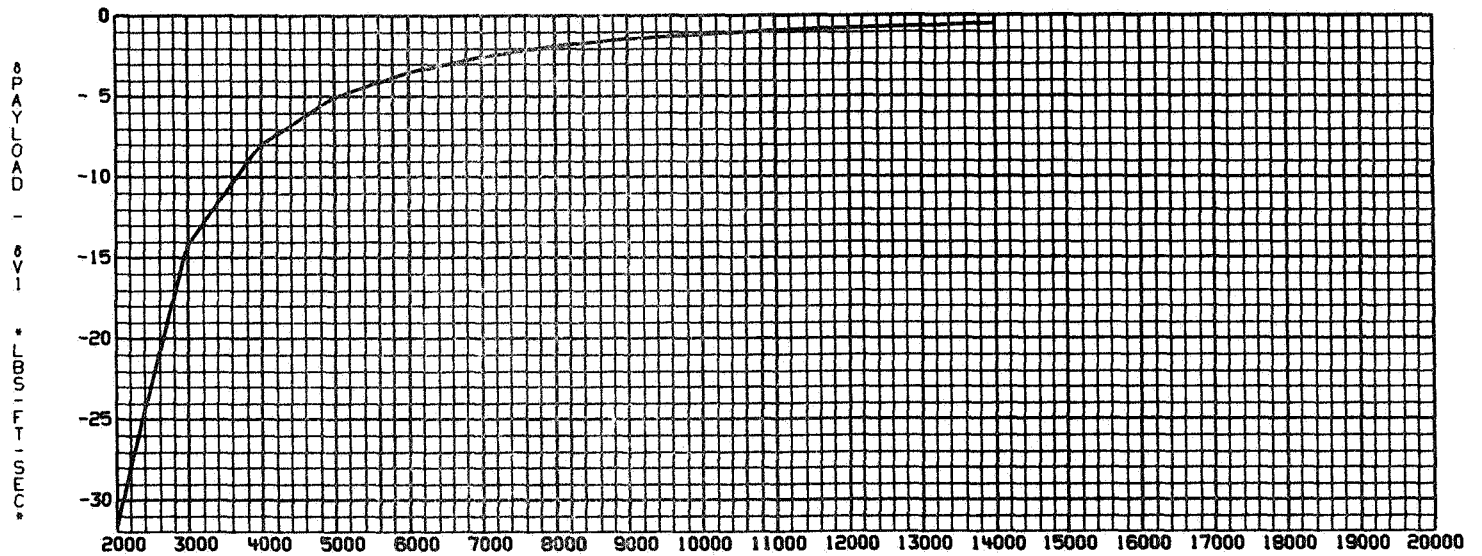
ON ORBIT VELOCITY *FT/SEC*

Figure 3-61

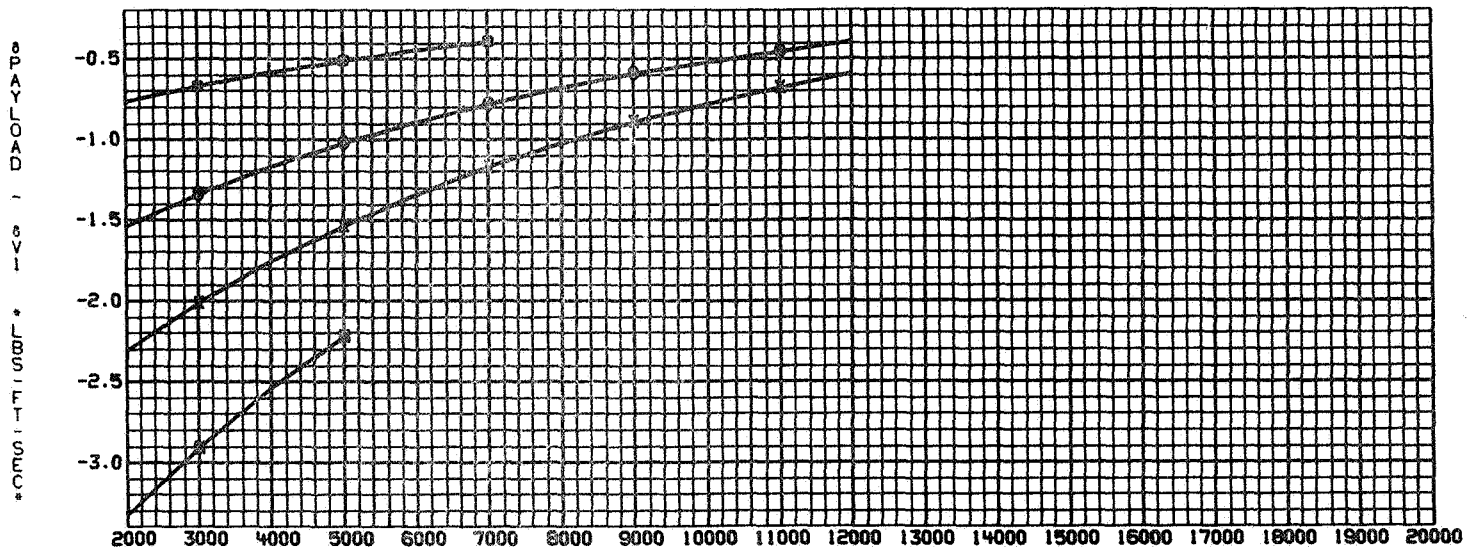
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



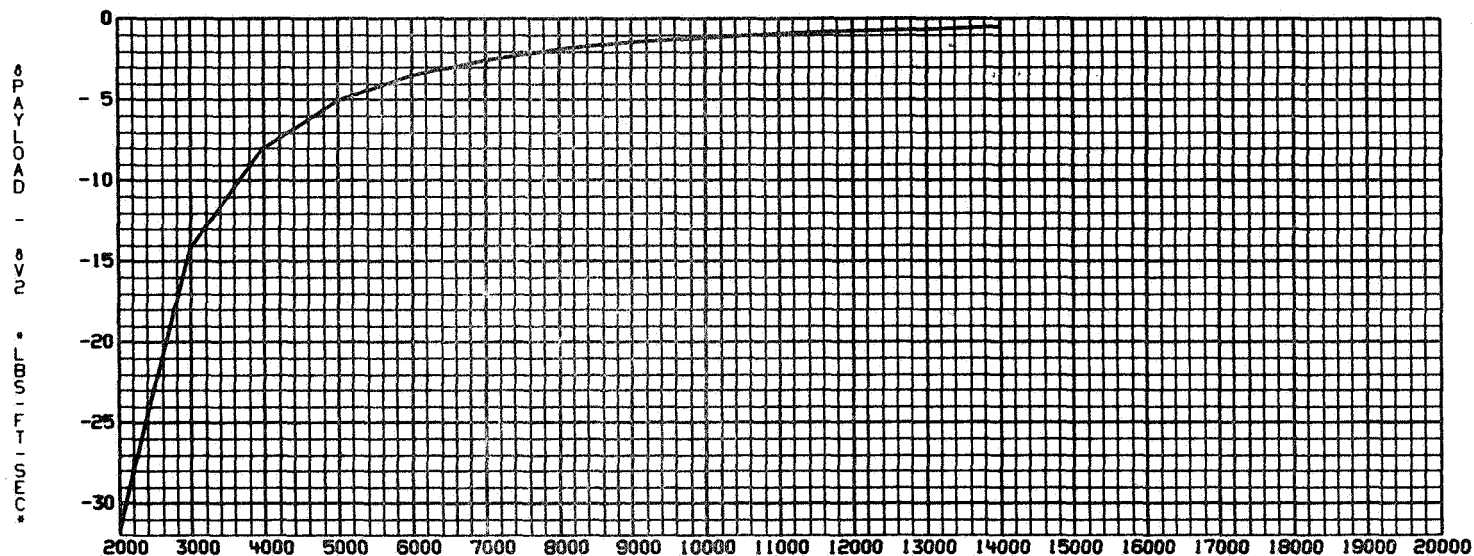
ON ORBIT VELOCITY *FT/SEC*

Figure 3-62

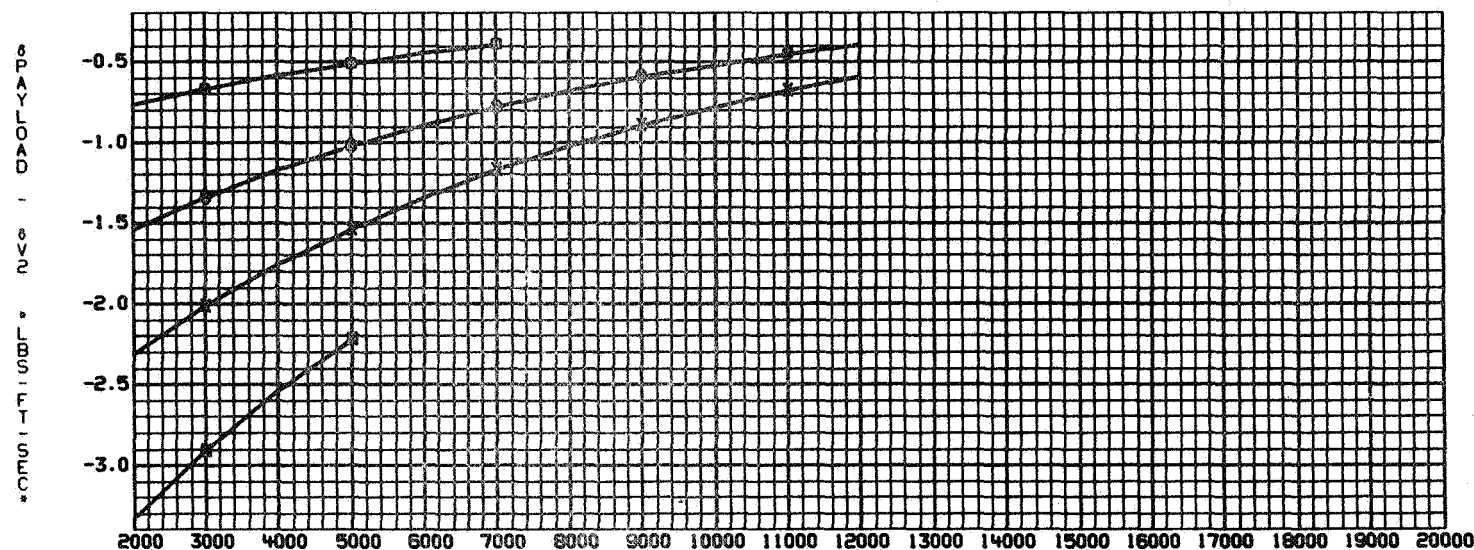
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-63

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

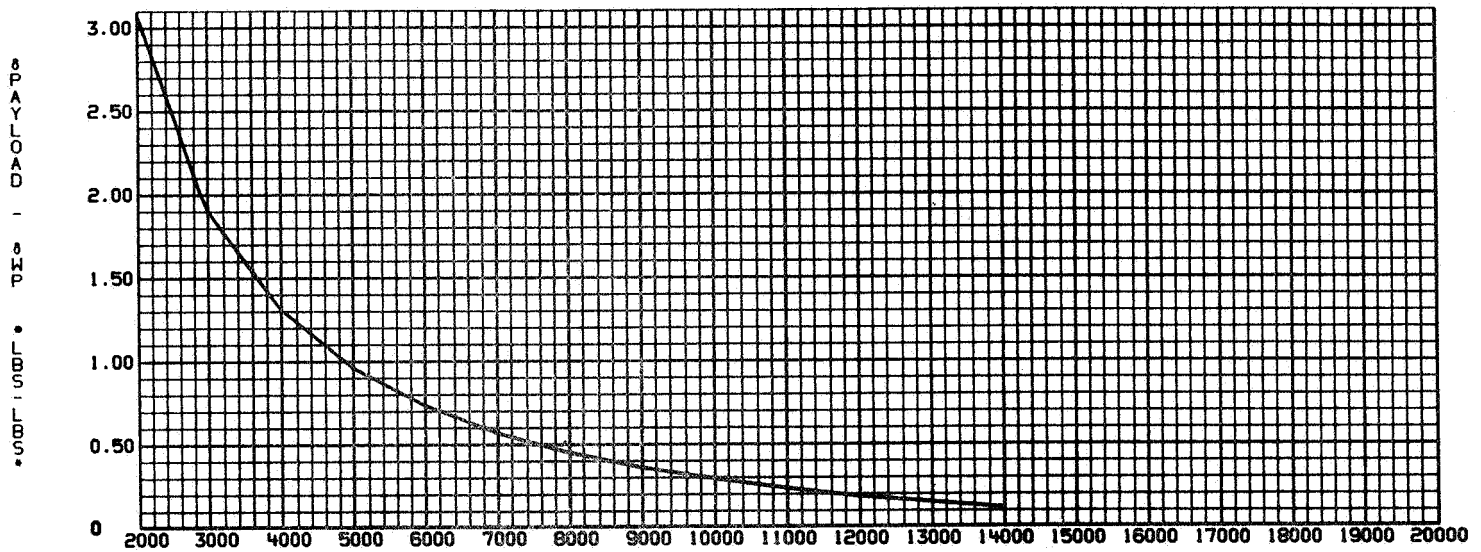


Figure 3-64

ALL FIXED IGNITION WEIGHTS

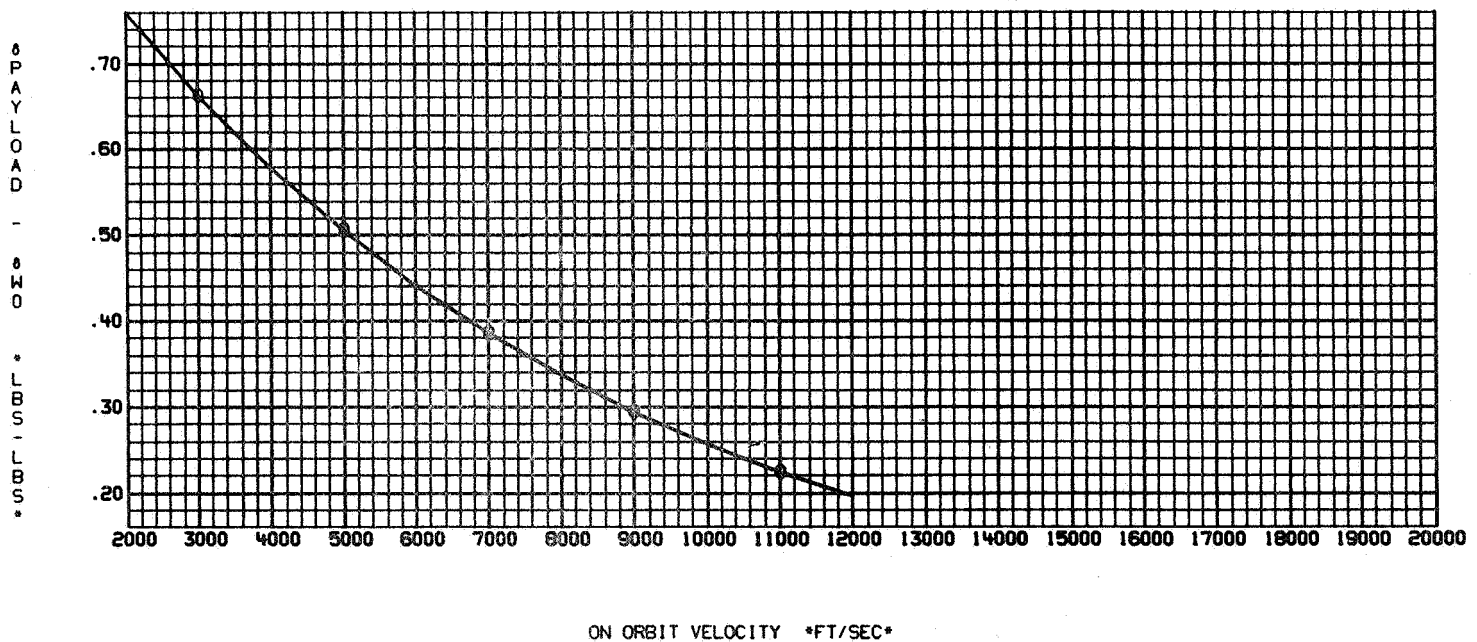
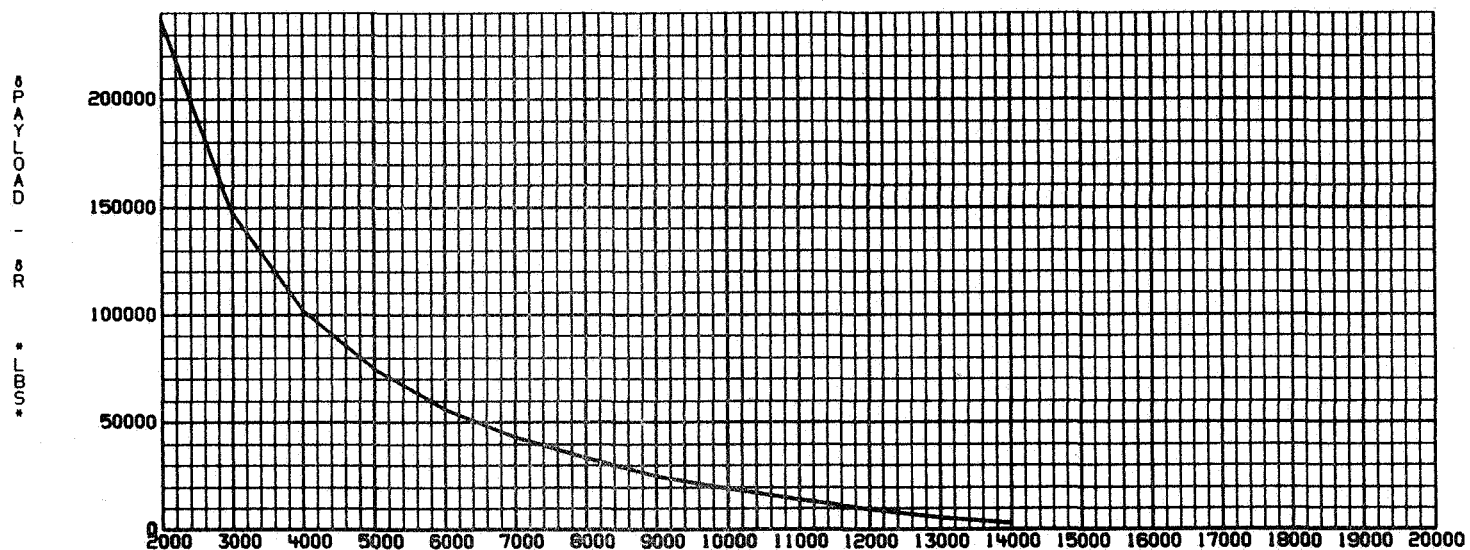


Figure 3-65

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.

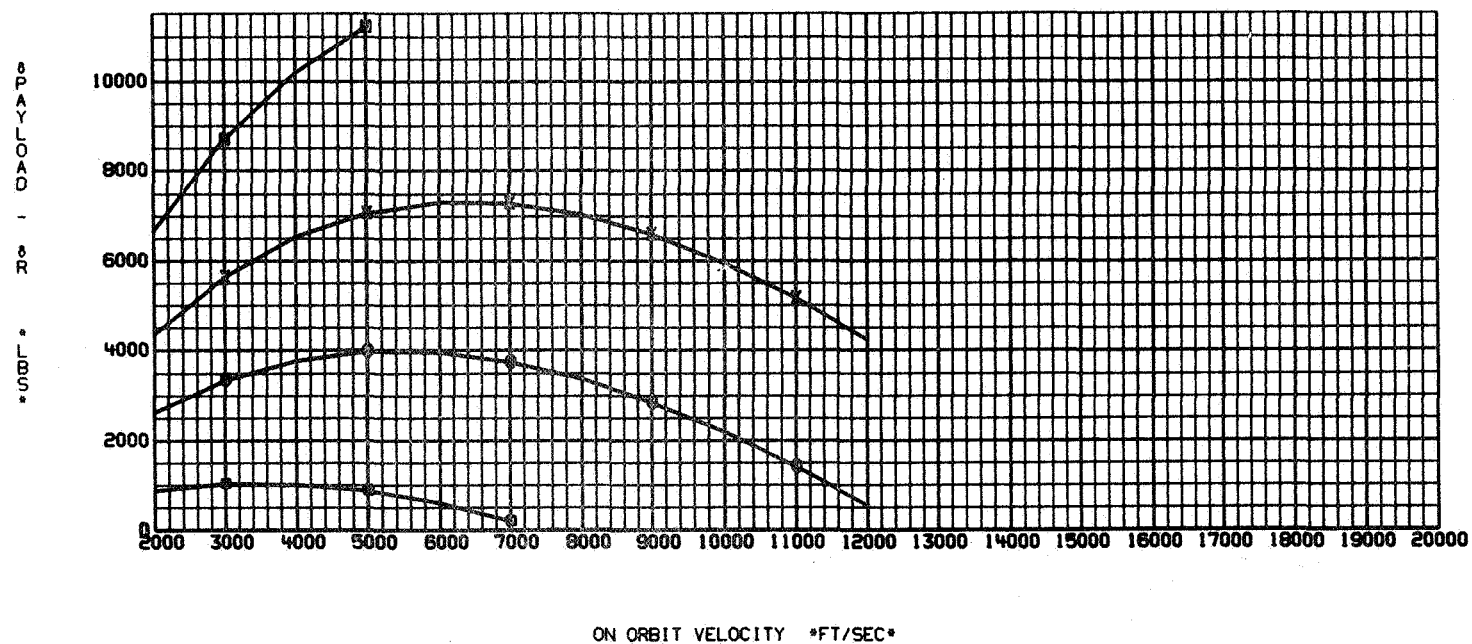


Figure 3-66

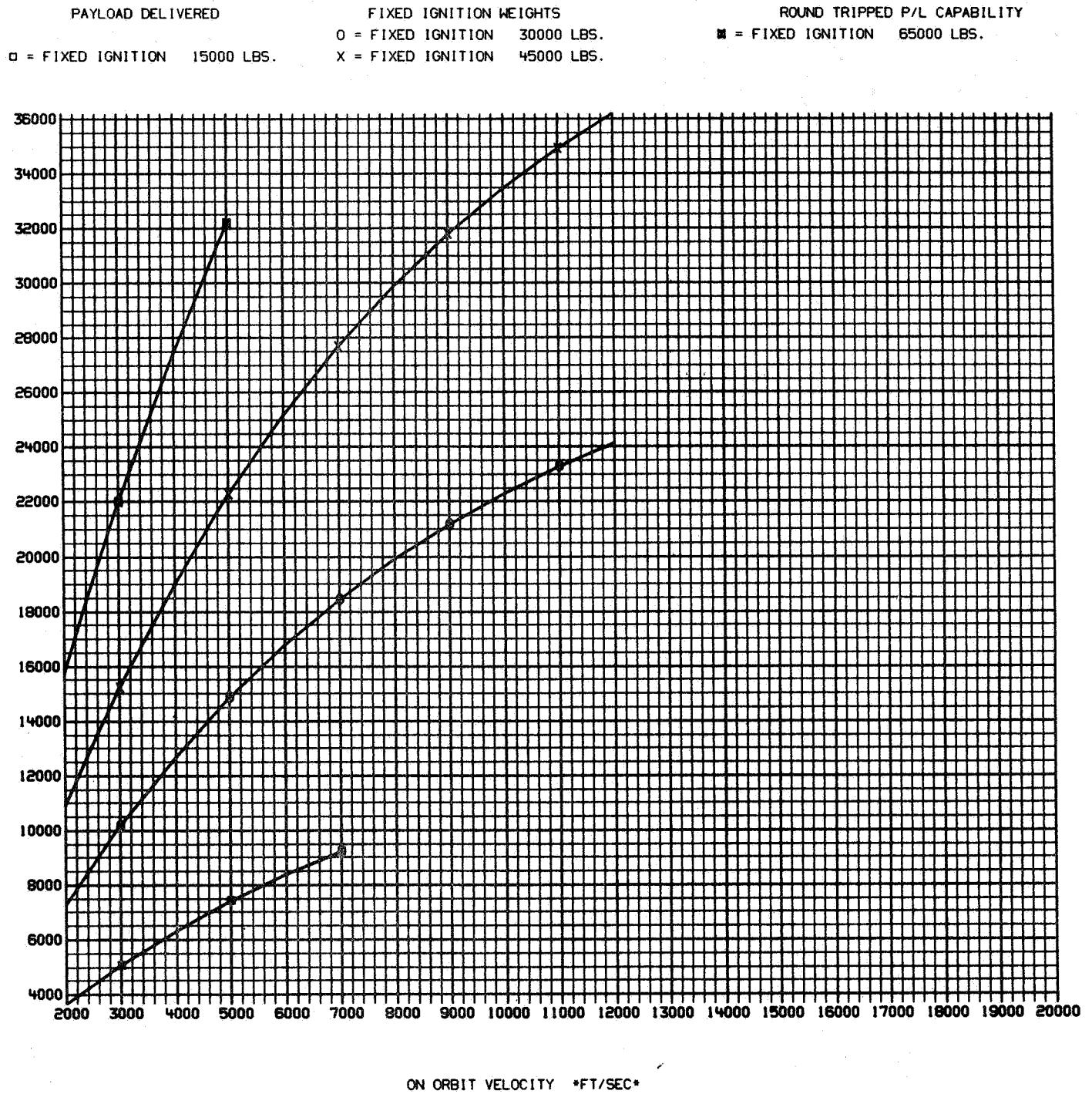


Figure 3-67

MODE 2

PAYLOAD RETURNED		36295 LBS. FIXED PROPELLANT WEIGHT	TUG - P/L RETRIEVAL CAPABILITY
• = FIXED PROPELLANT 36295 LBS.	0 = FIXED IGNITION 30000 LBS.		■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.		

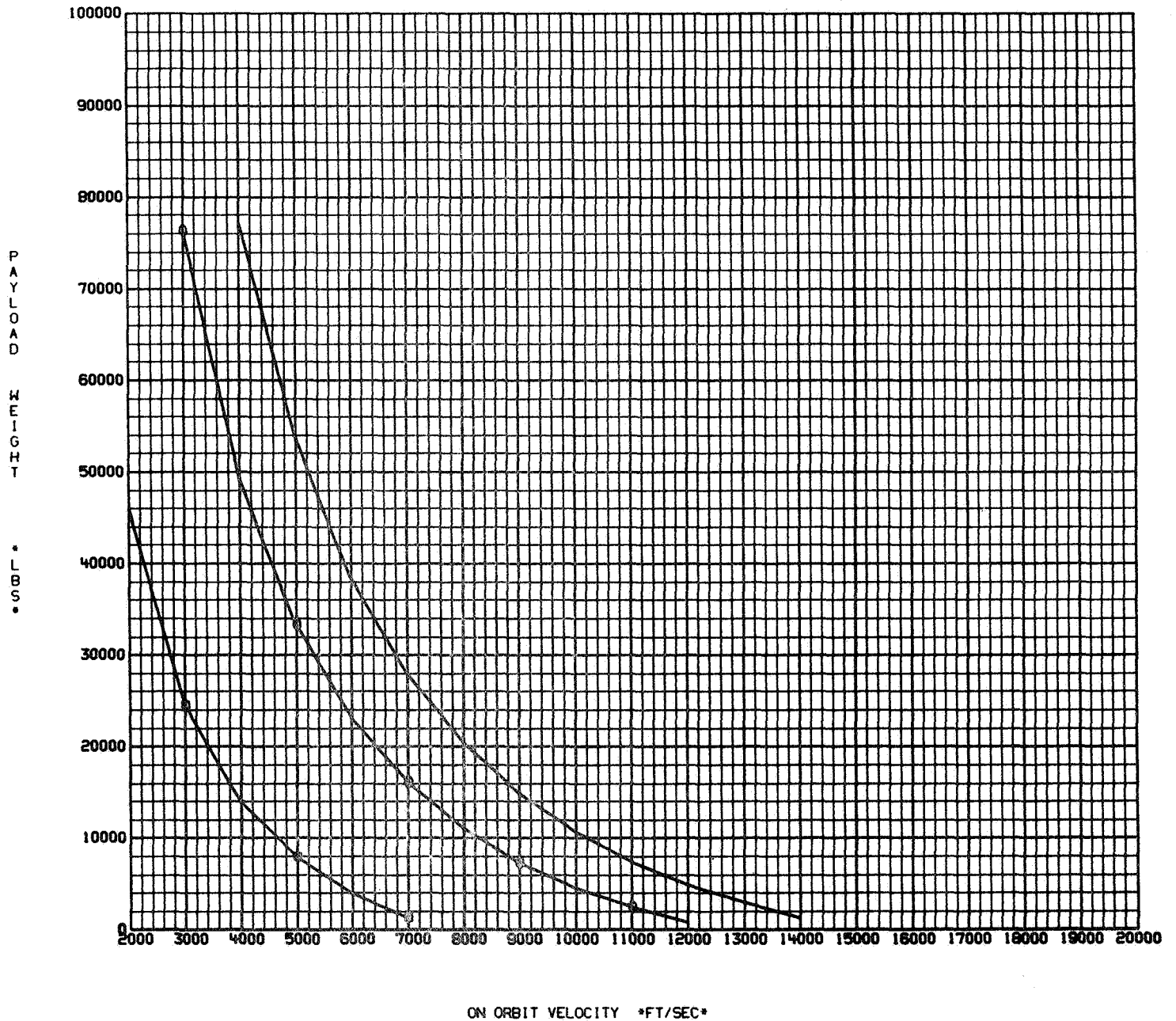
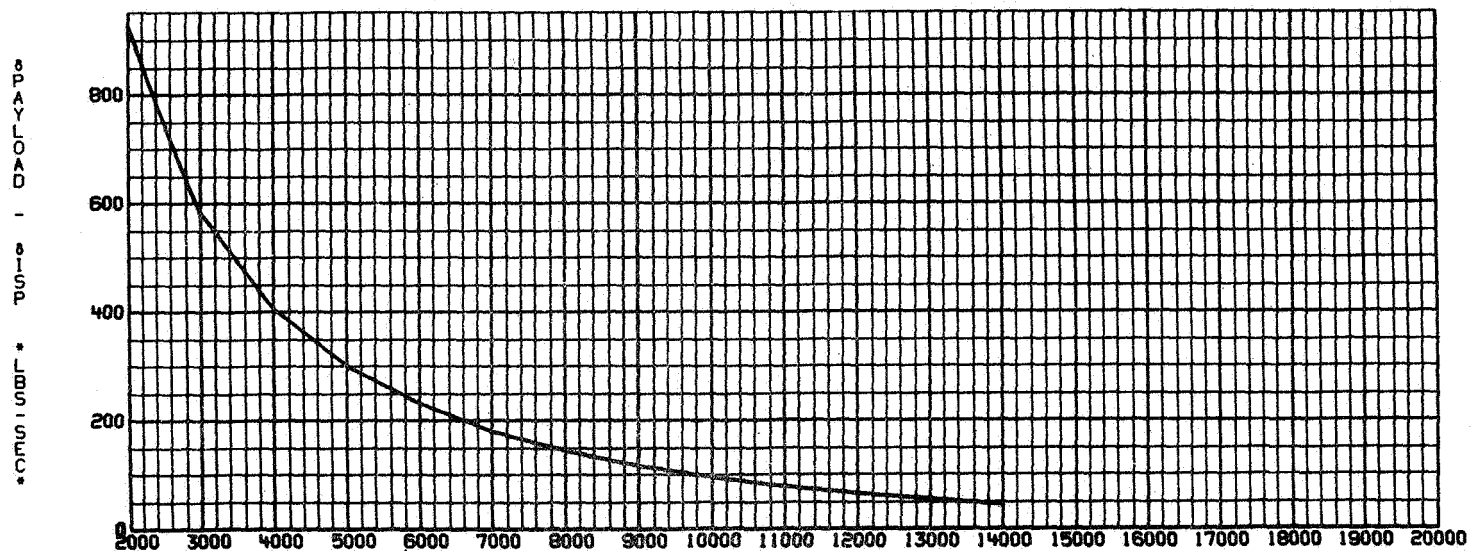


Figure 3-68

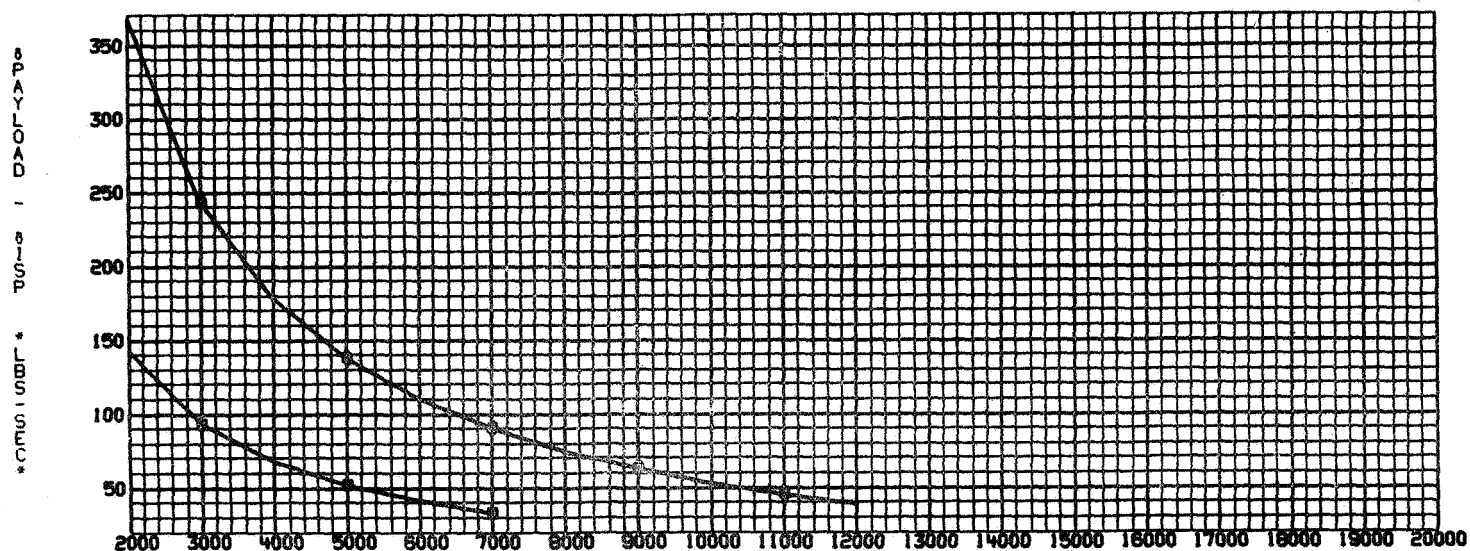
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



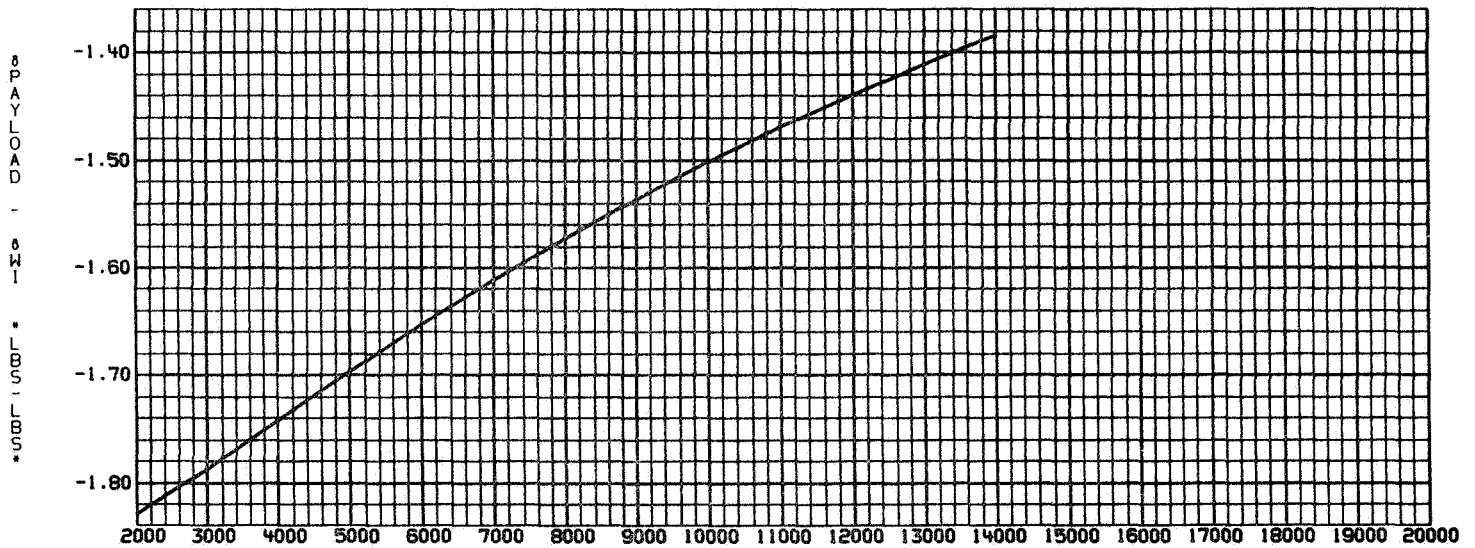
ON ORBIT VELOCITY *FT/SEC*

Figure 3-69

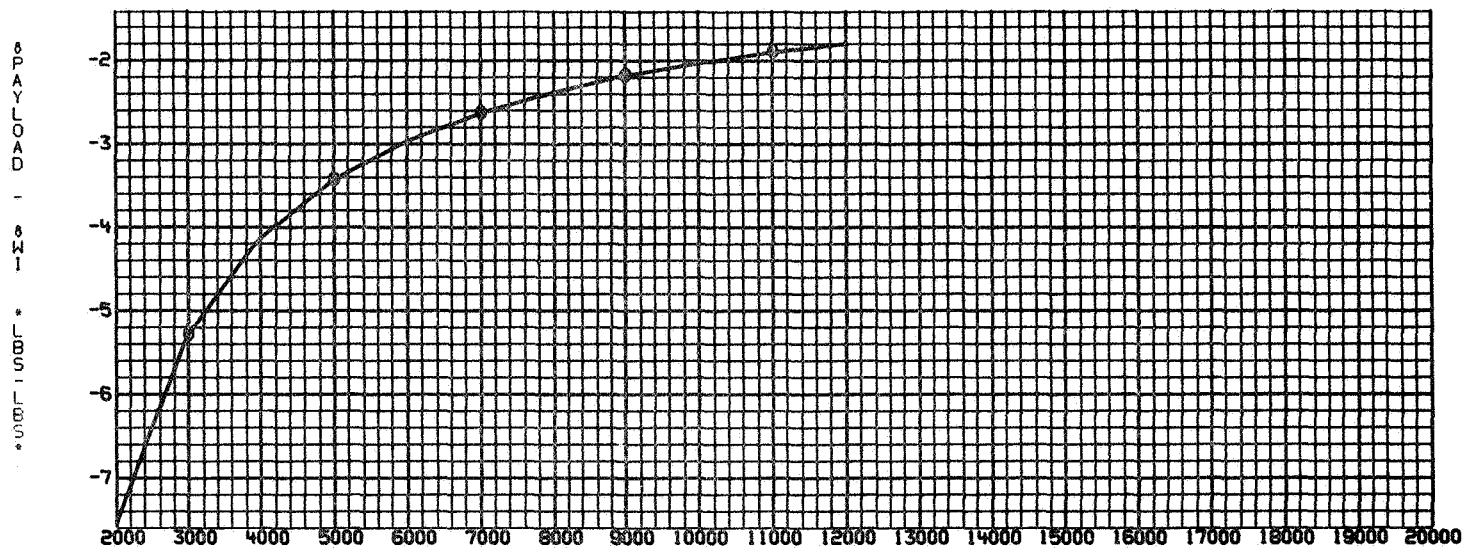
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-70

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

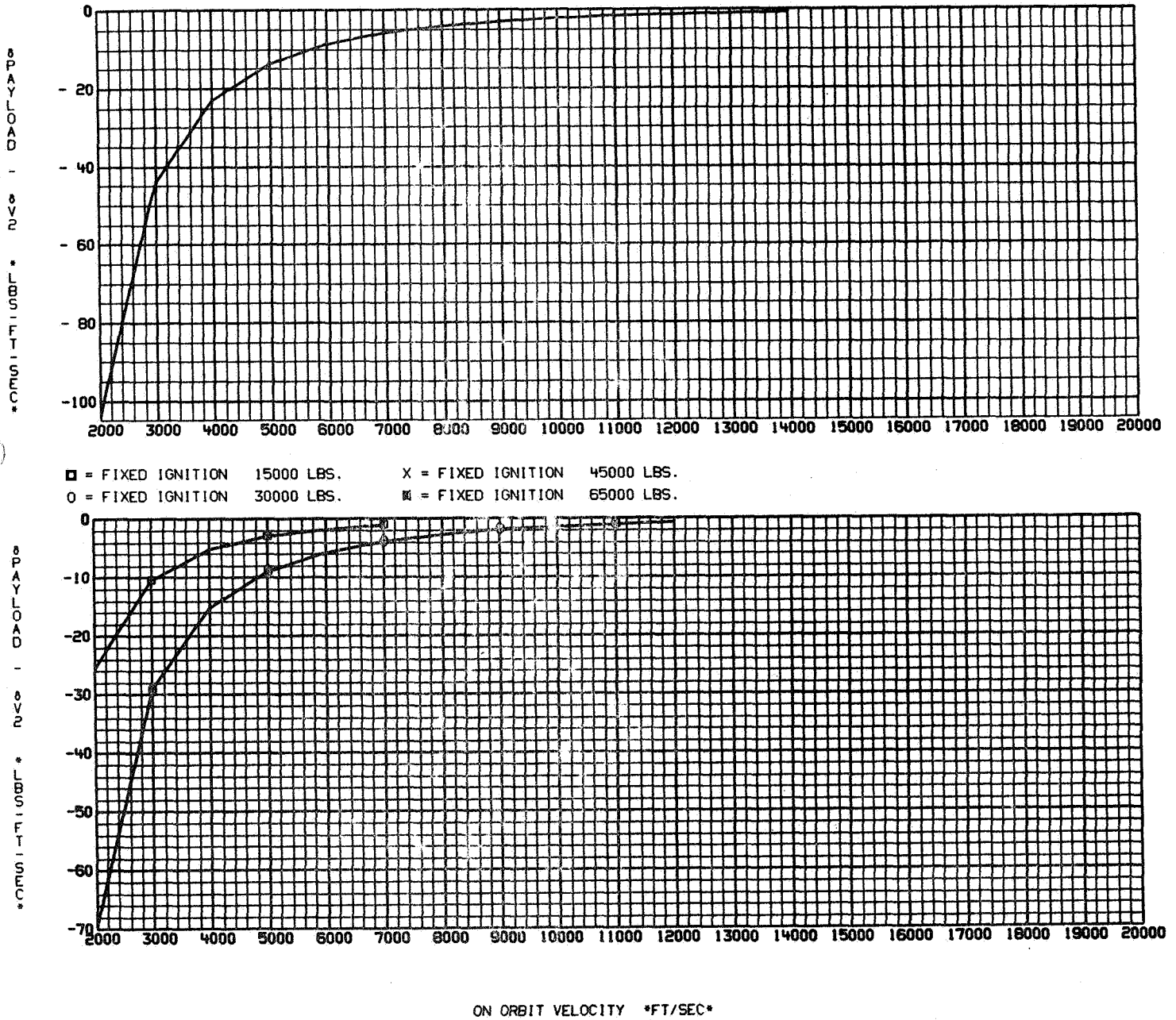


Figure 3-71

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

36295 LBS. FIXED PROPELLANT WEIGHT

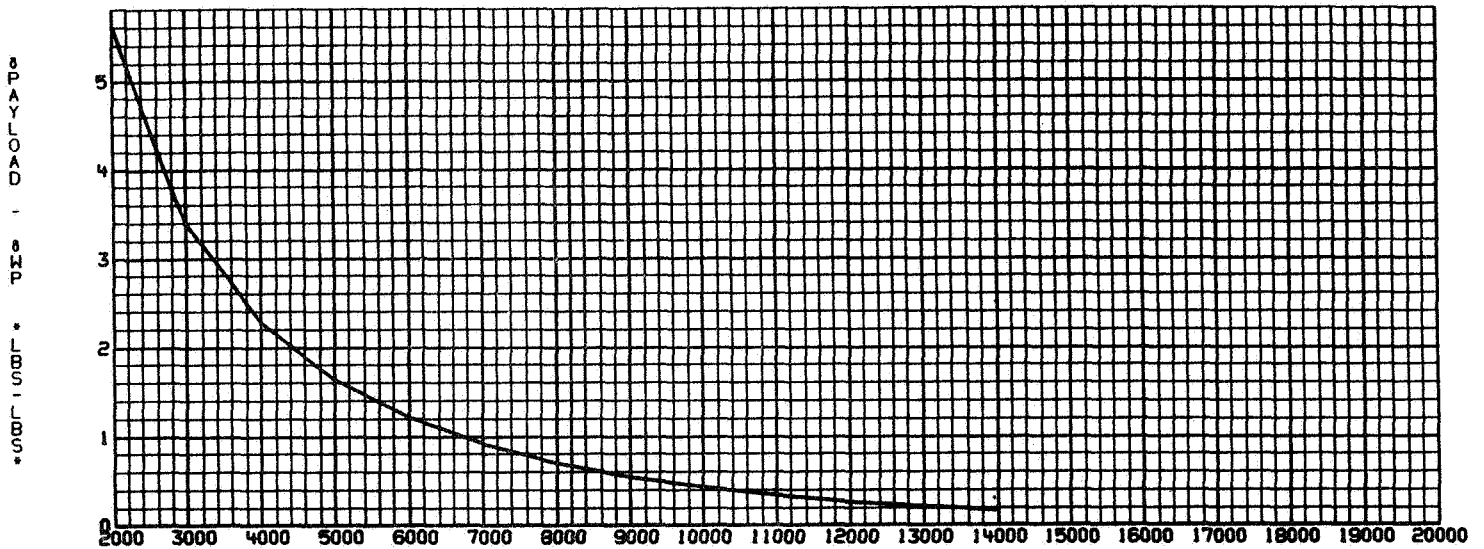


Figure 3-72

ALL FIXED IGNITION WEIGHTS

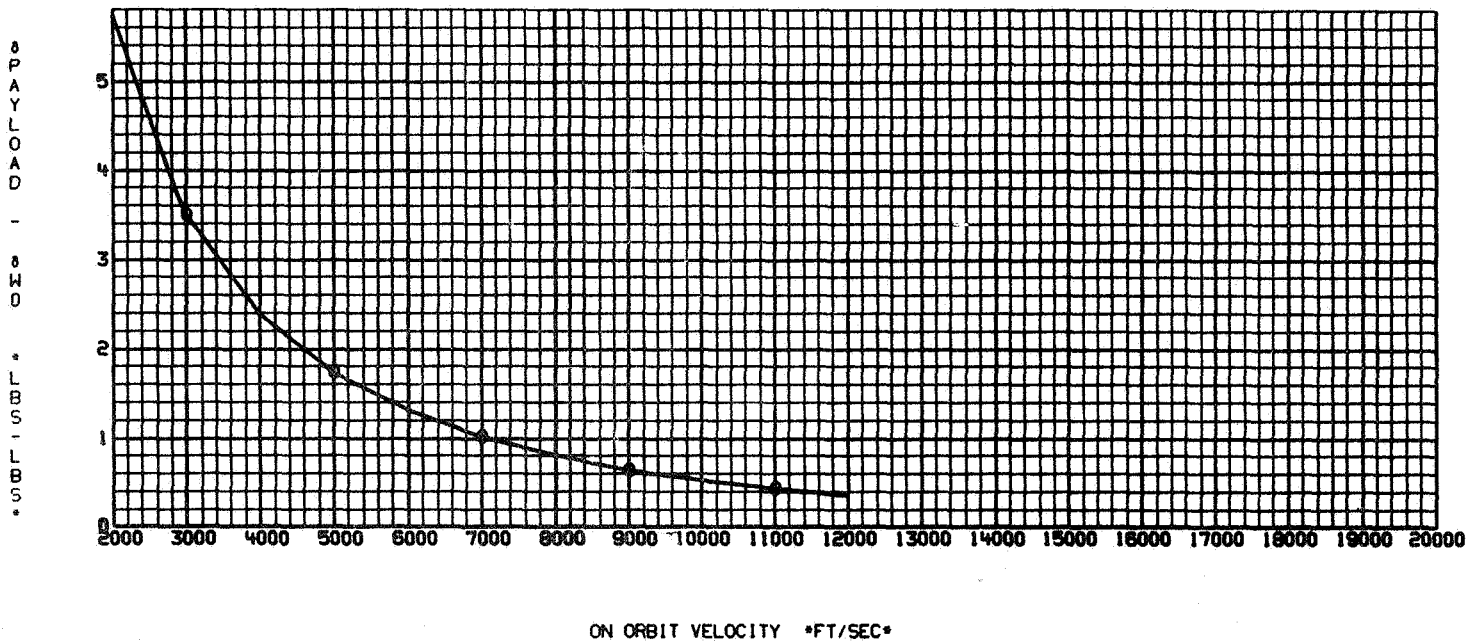


Figure 3-73

NOTE

Offloaded propellant
in Mode 2 is not
a function of ΔV

Figure 3-74

3-66

MODE 3

PAYLOAD DELIVERED		36295 LBS. FIXED PROPELLANT WEIGHT		EXPENDABLE P/L ** REUSEABLE TUG	
• = FIXED PROPELLANT 36295 LBS.		O = FIXED IGNITION 30000 LBS.		■ = FIXED IGNITION 65000 LBS.	
□ = FIXED IGNITION 15000 LBS.		X = FIXED IGNITION 45000 LBS.			

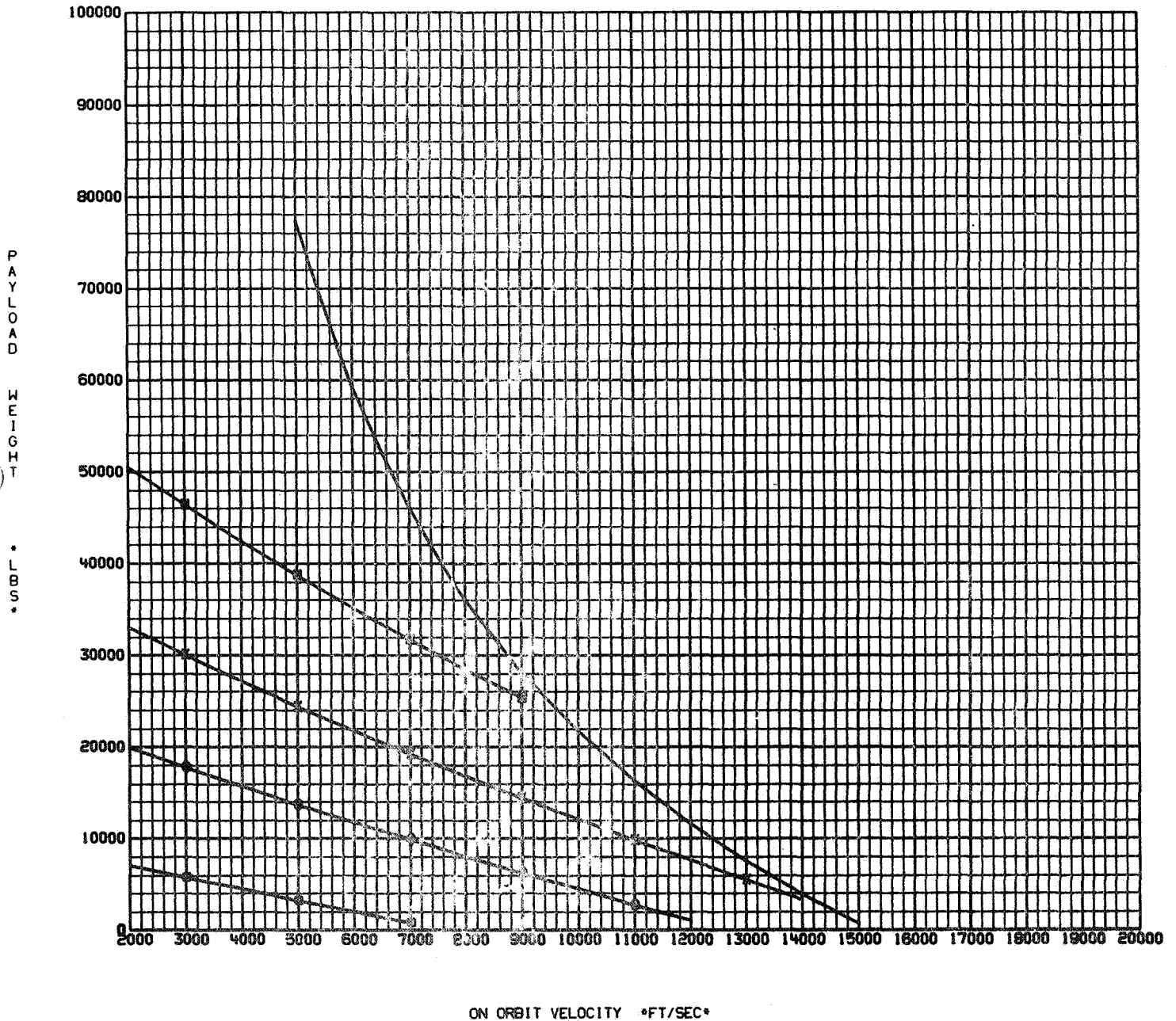
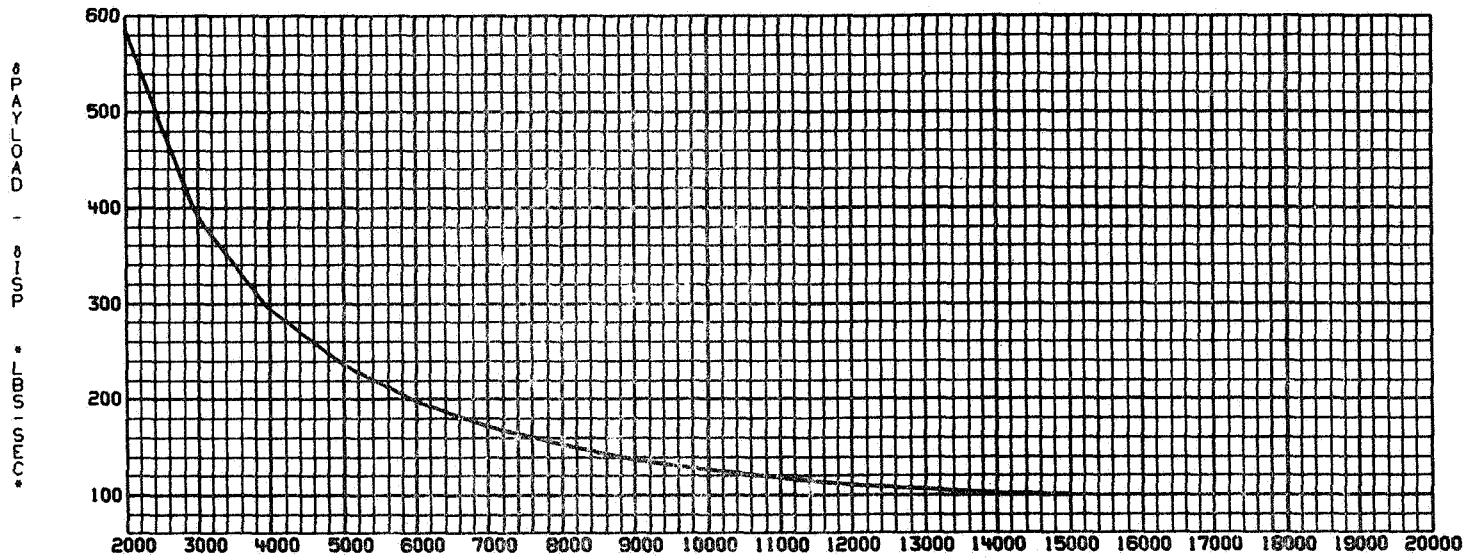


Figure 3-75

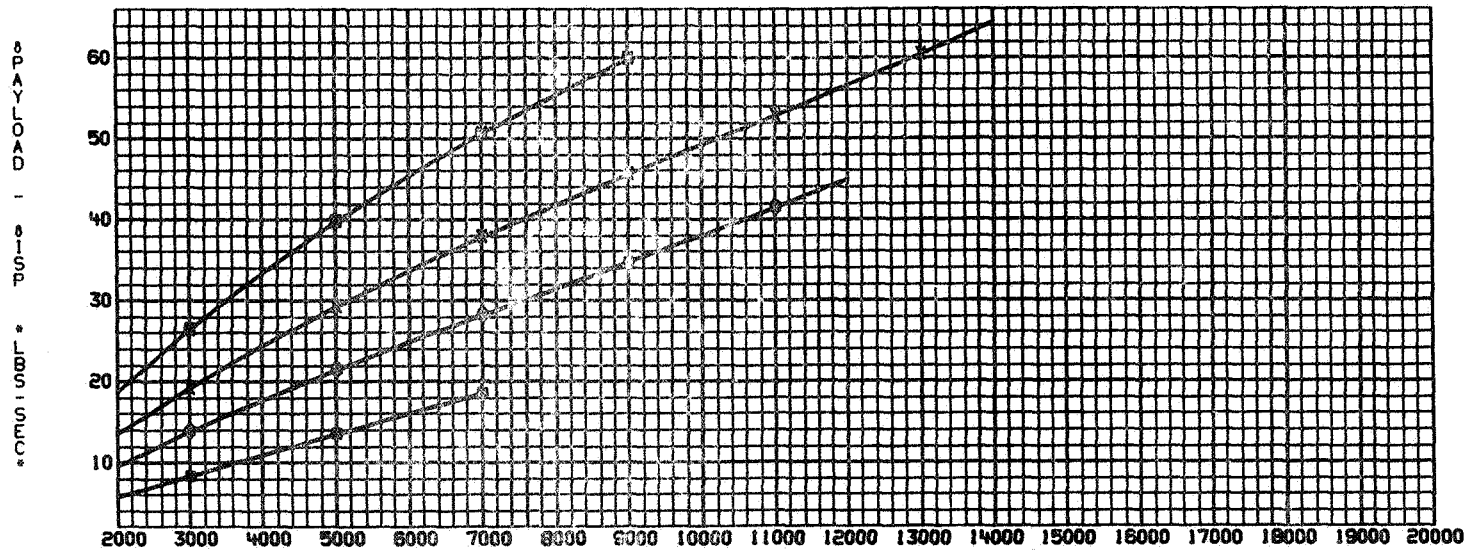
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



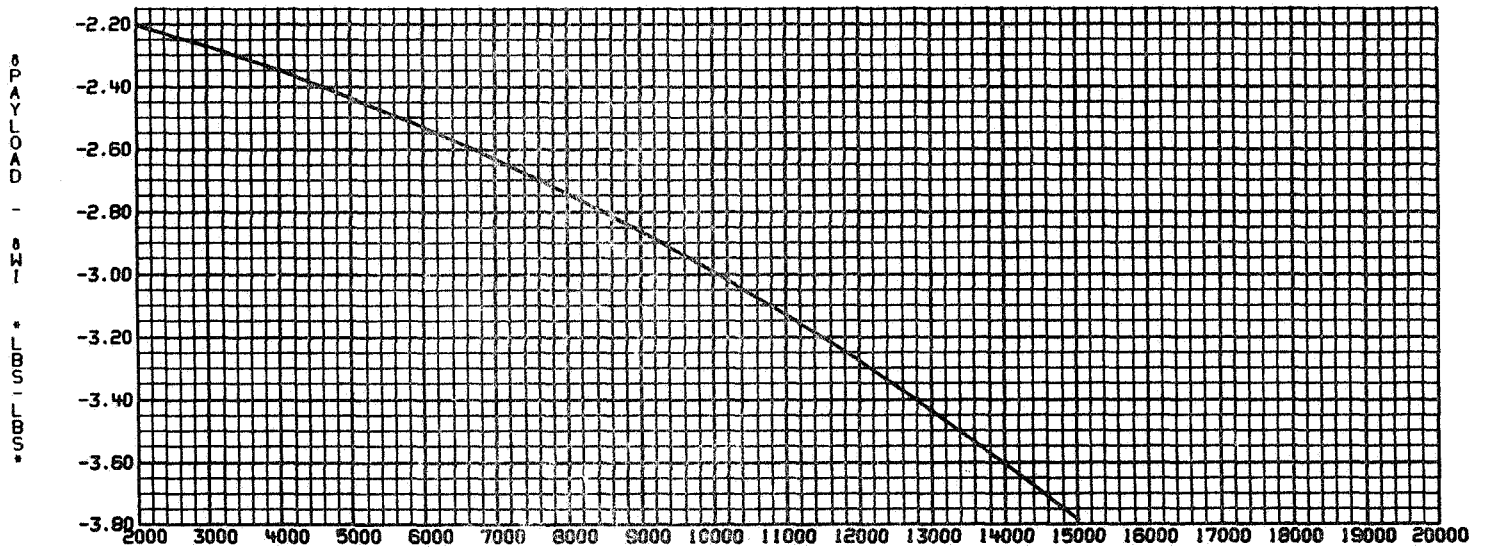
ON ORBIT VELOCITY *FT/SEC*

Figure 3-76

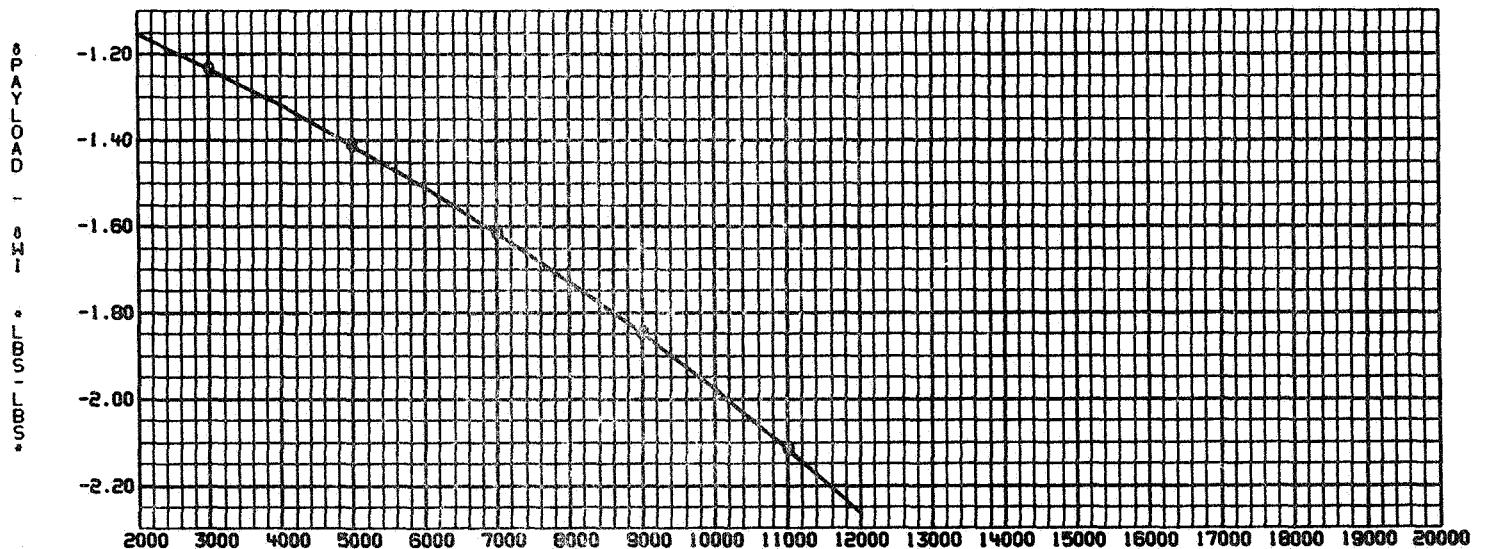
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-77

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

36295 LBS. FIXED PROPELLANT WEIGHT

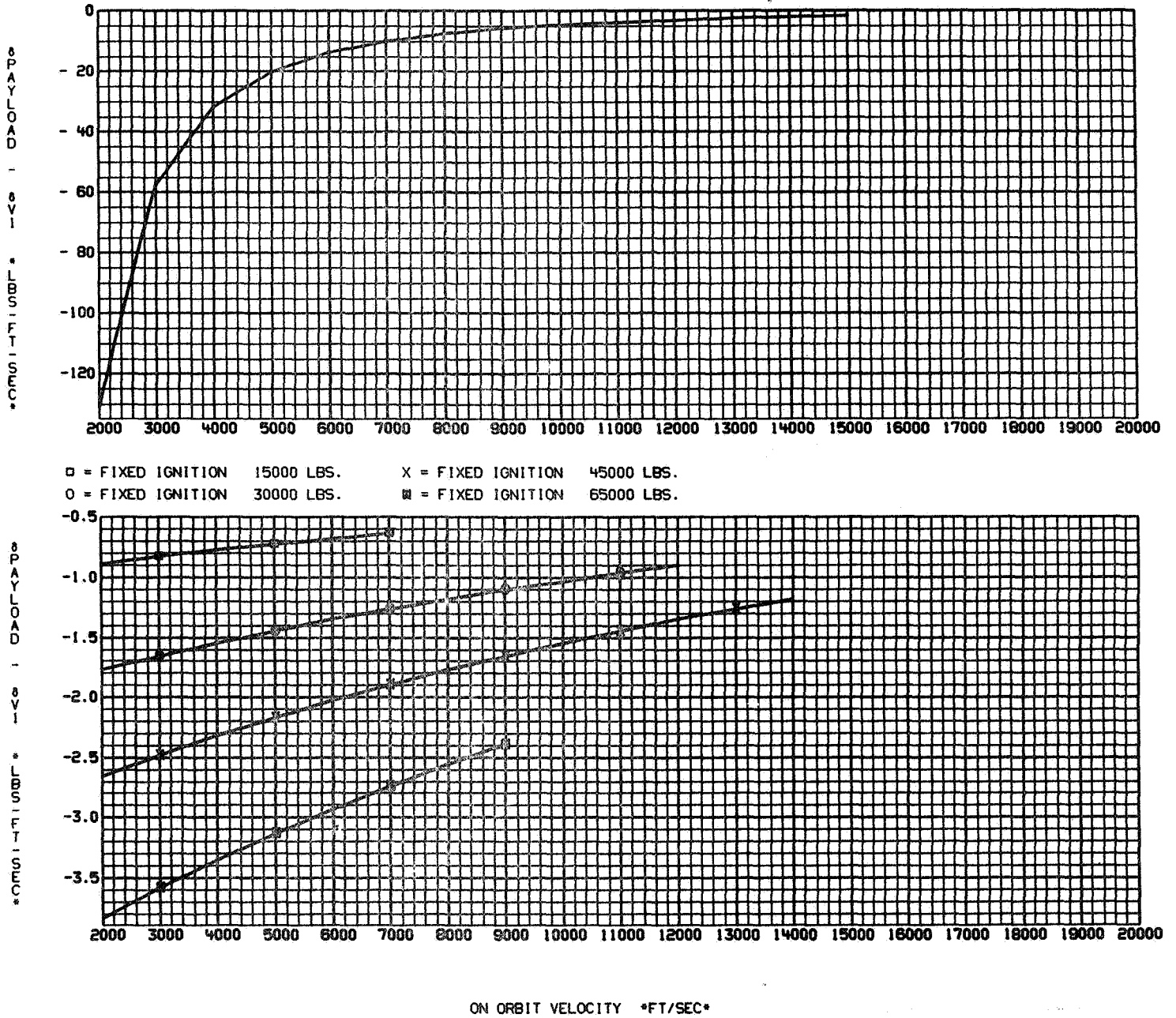


Figure 3-78

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

36295 LBS. FIXED PROPELLANT WEIGHT

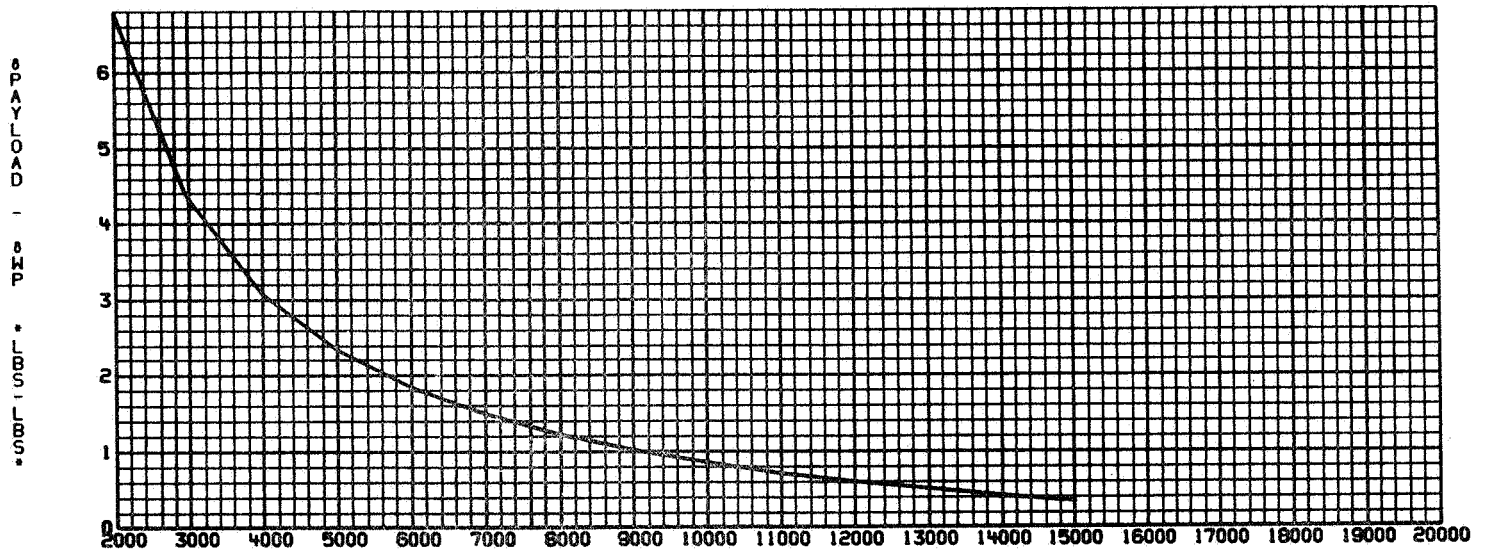


Figure 3-79

ALL FIXED IGNITION WEIGHTS

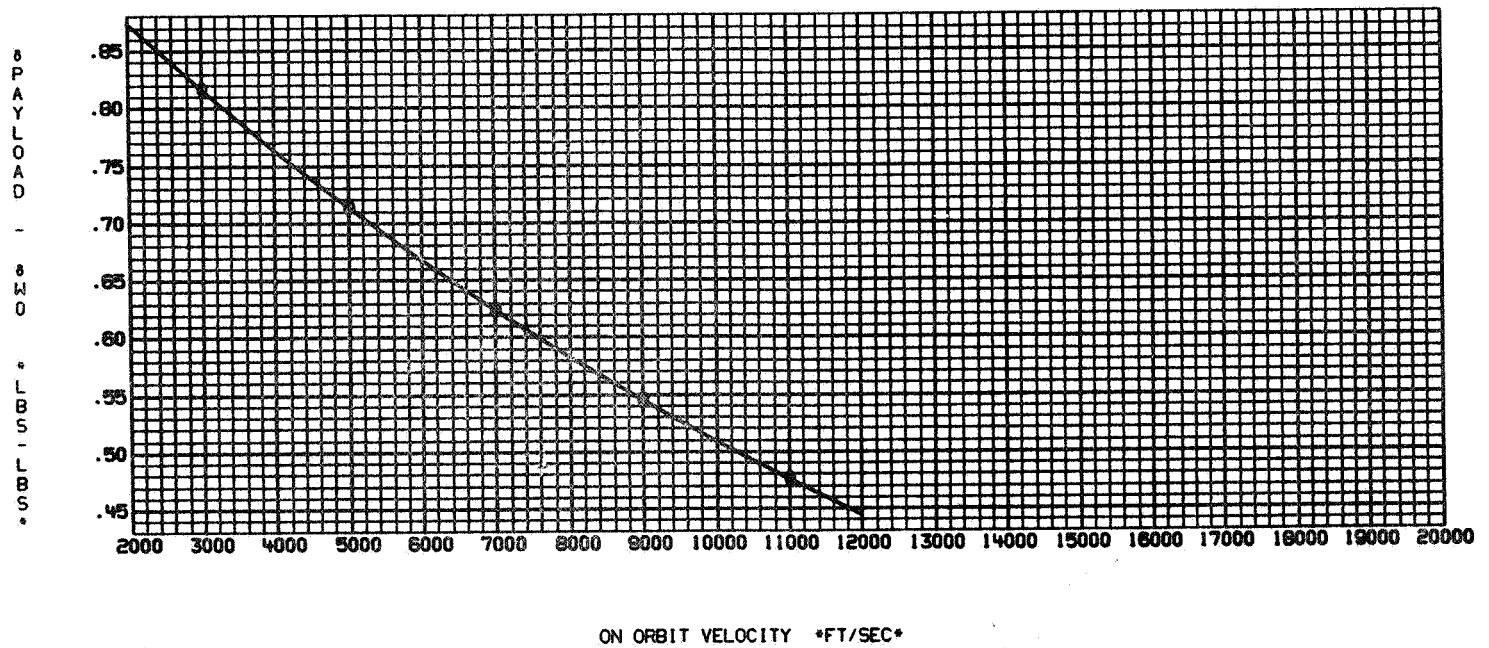


Figure 3-80

PAYLOAD DELIVERED
 O = FIXED IGNITION 15000 LBS.
 X = FIXED IGNITION 30000 LBS.
 EXPENDABLE P/L ** REUSEABLE TUG
 ■ = FIXED IGNITION 65000 LBS.

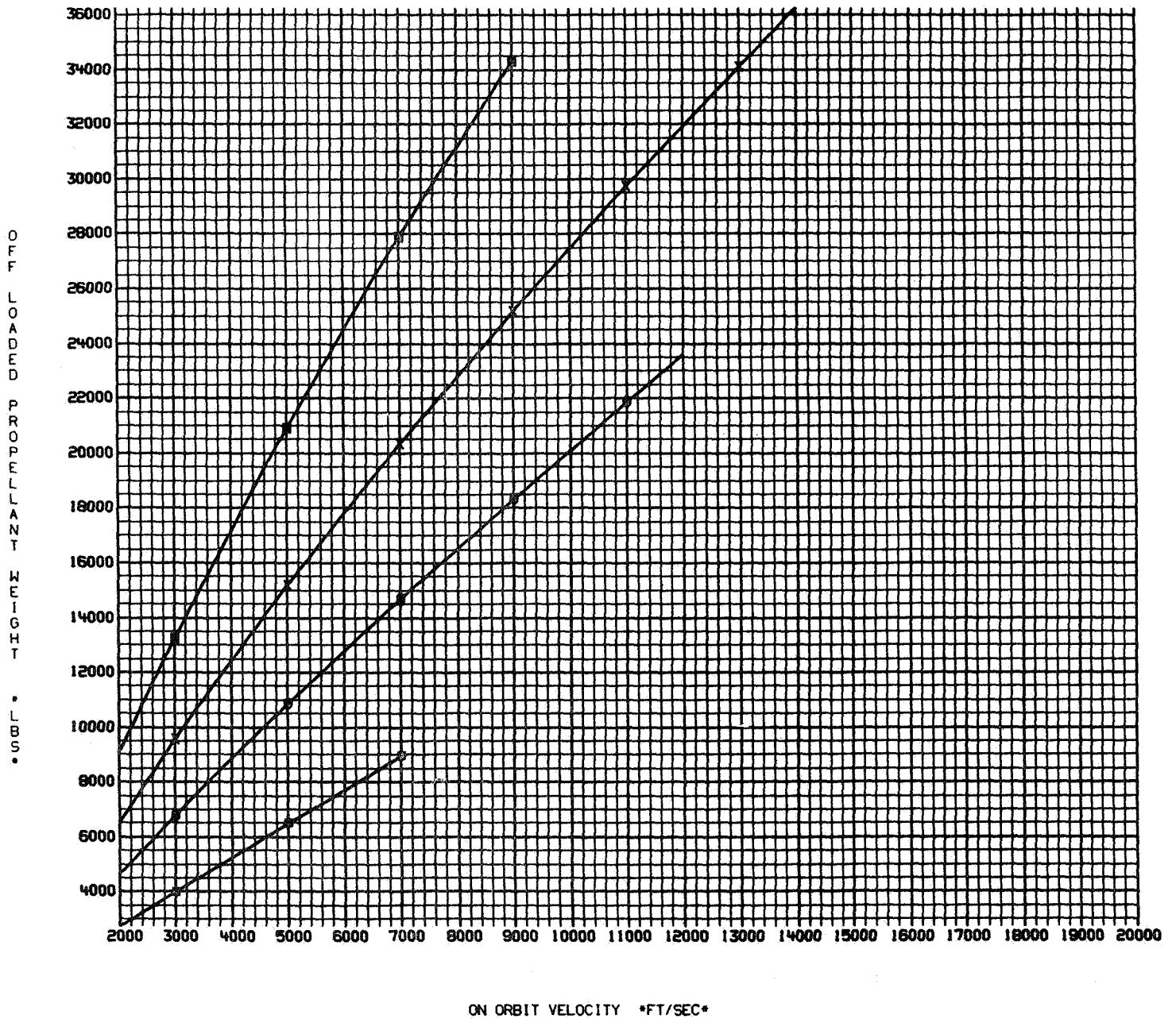


Figure 3-81

MODE 4

PAYLOAD DELIVERED	36295 LBS. FIXED PROPELLANT WEIGHT	EXPENDABLE TUG AND P/L
• = FIXED PROPELLANT 36295 LBS.	O = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.	

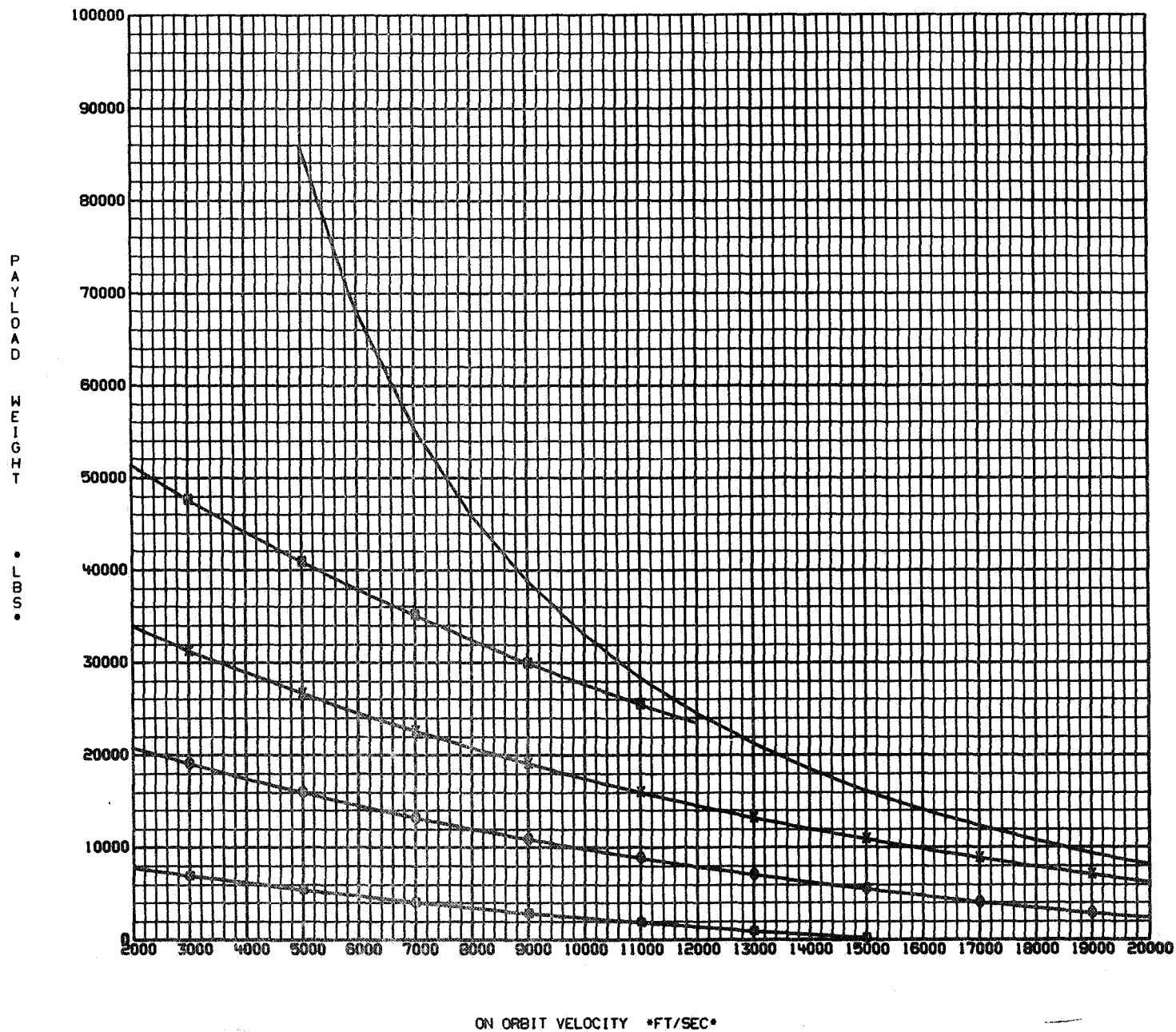


Figure 3-82

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

36295 LBS. FIXED PROPELLANT WEIGHT

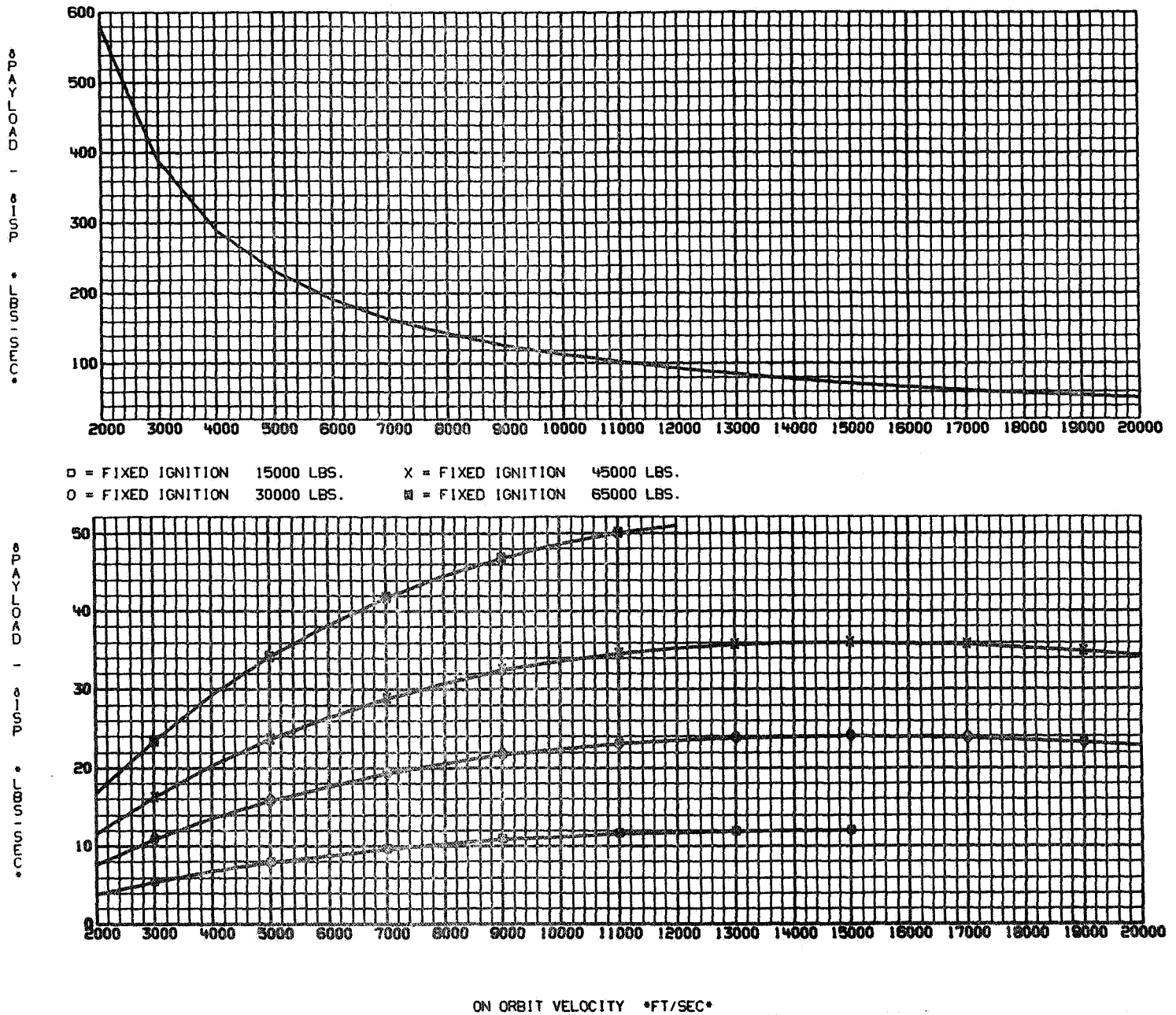
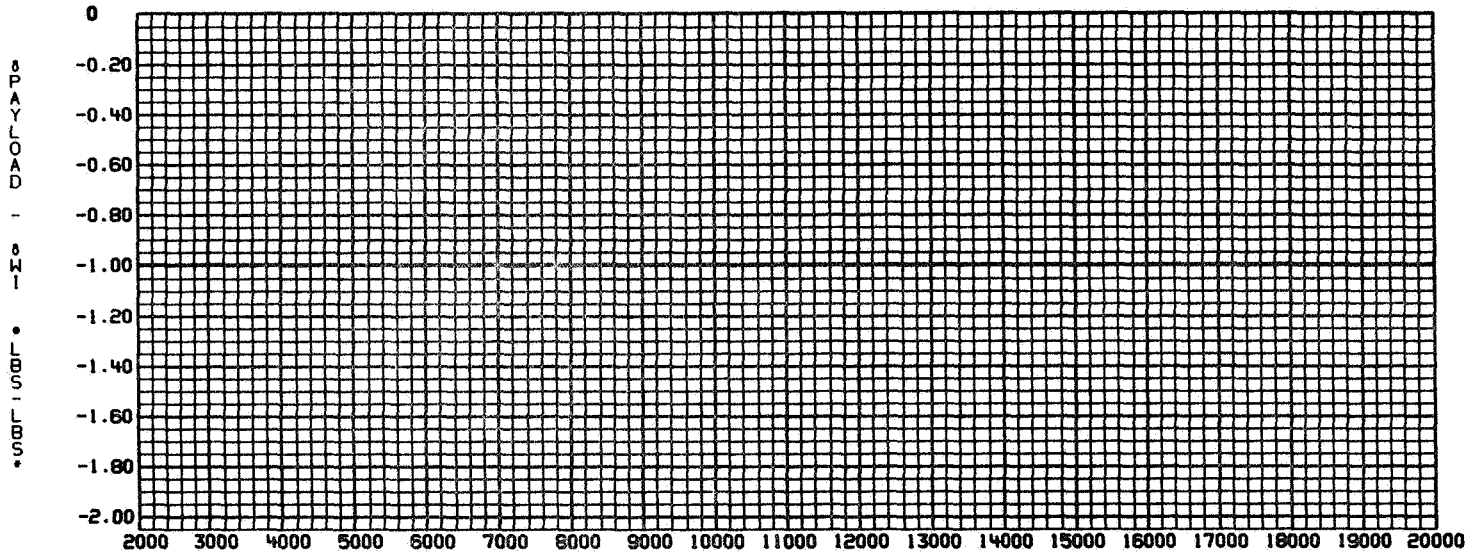


Figure 3-83

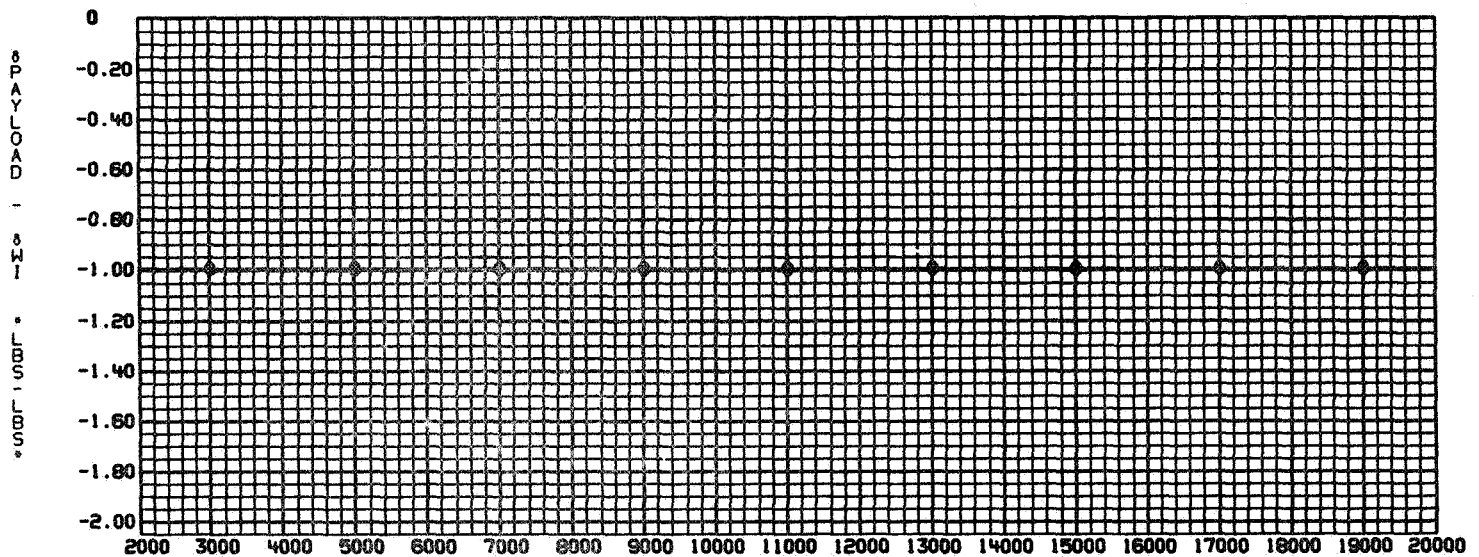
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

36295 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



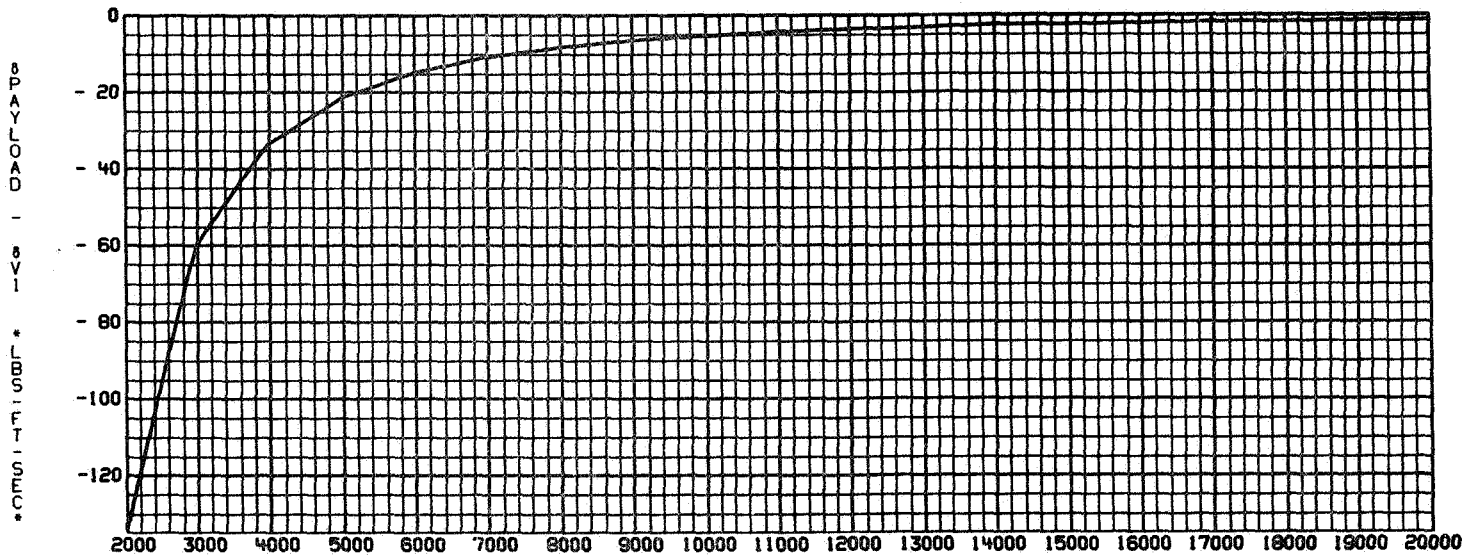
ON ORBIT VELOCITY *FT/SEC*

Figure 3-84

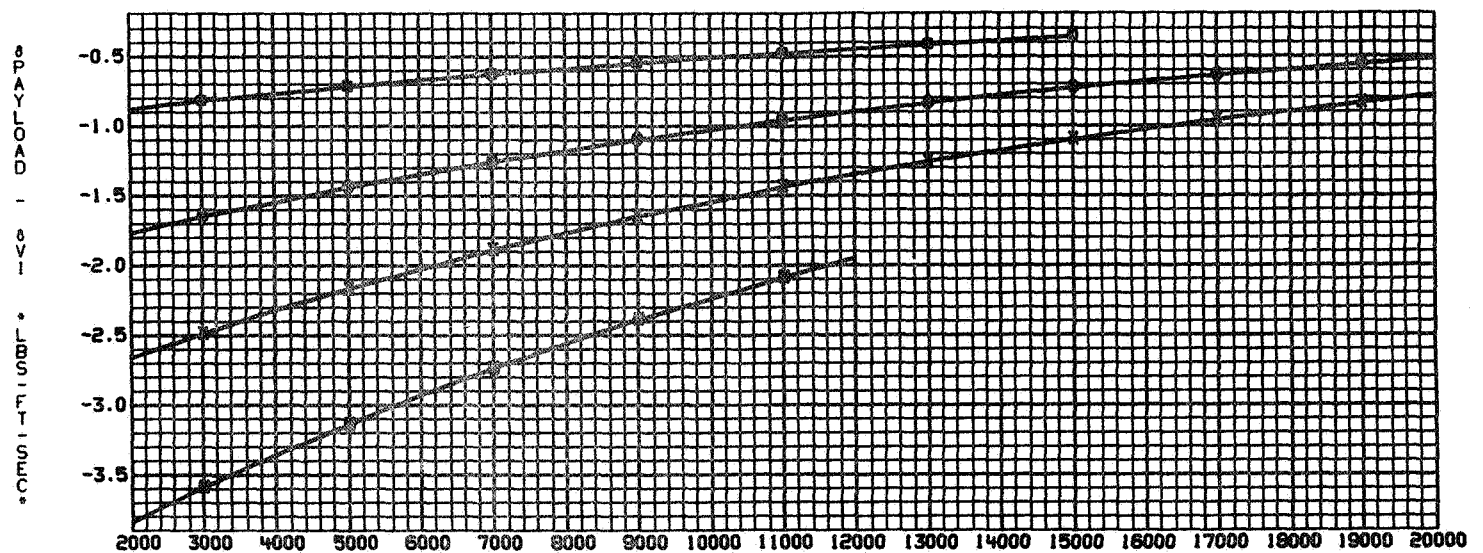
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

36295 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-85

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

36295 LBS. FIXED PROPELLANT WEIGHT

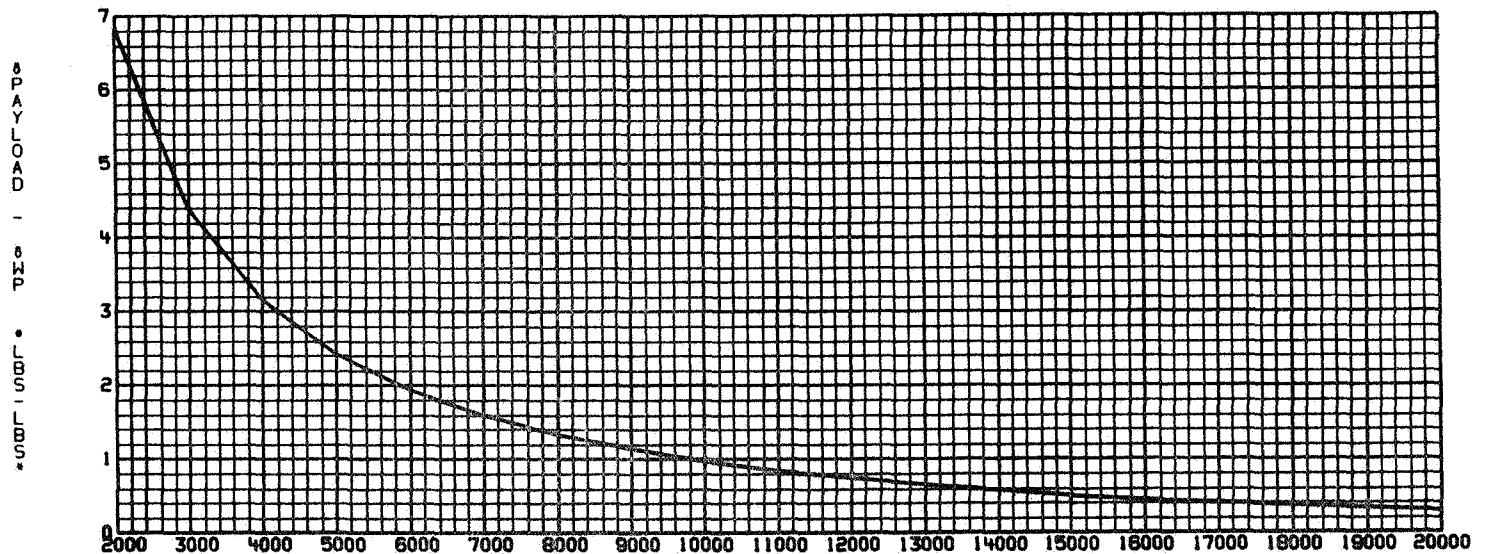


Figure 3-86

ALL FIXED IGNITION WEIGHTS

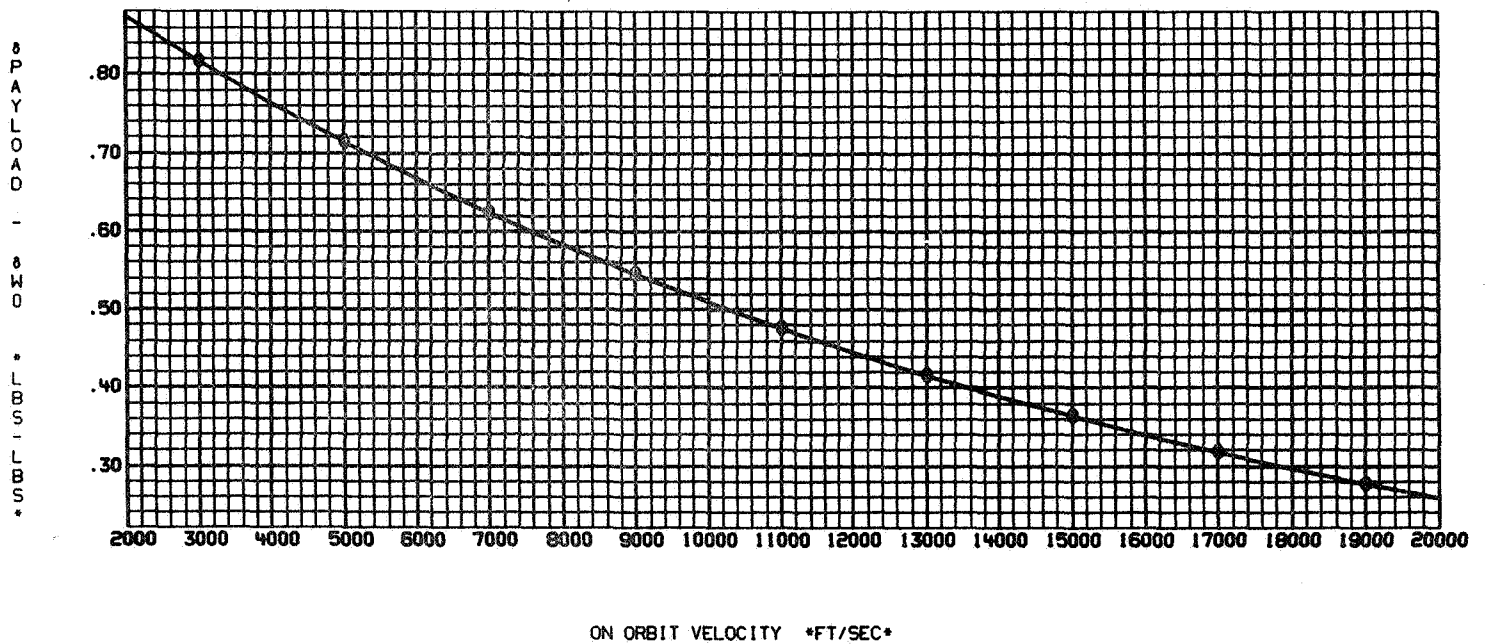


Figure 3-87

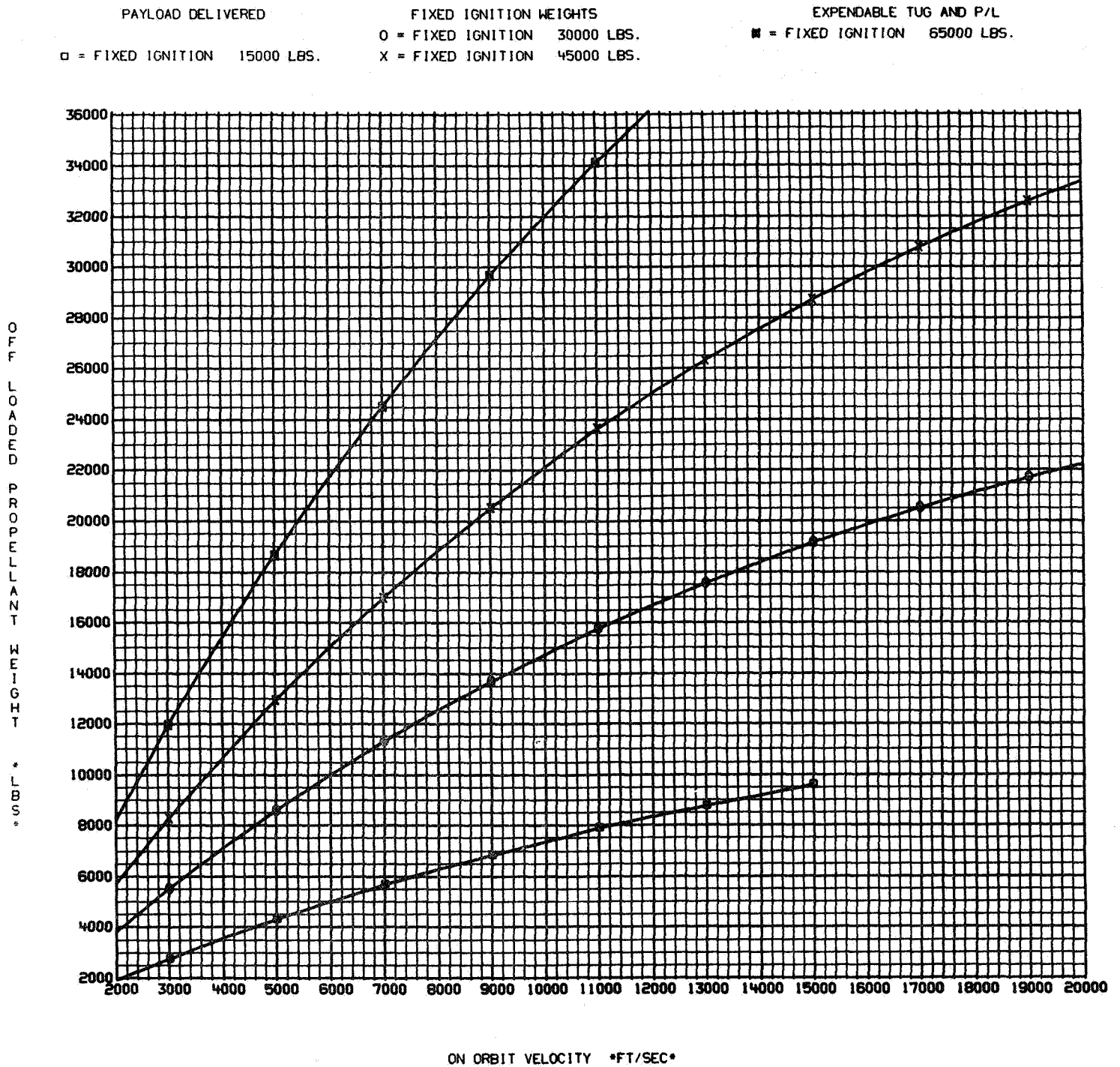


Figure 3-88

MODE 1

PAYLOAD DELIVERED	47830 LBS. FIXED PROPELLANT WEIGHT	ROUND TRIPPED P/L CAPABILITY
• = FIXED PROPELLANT 47830 LBS.	O = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.	

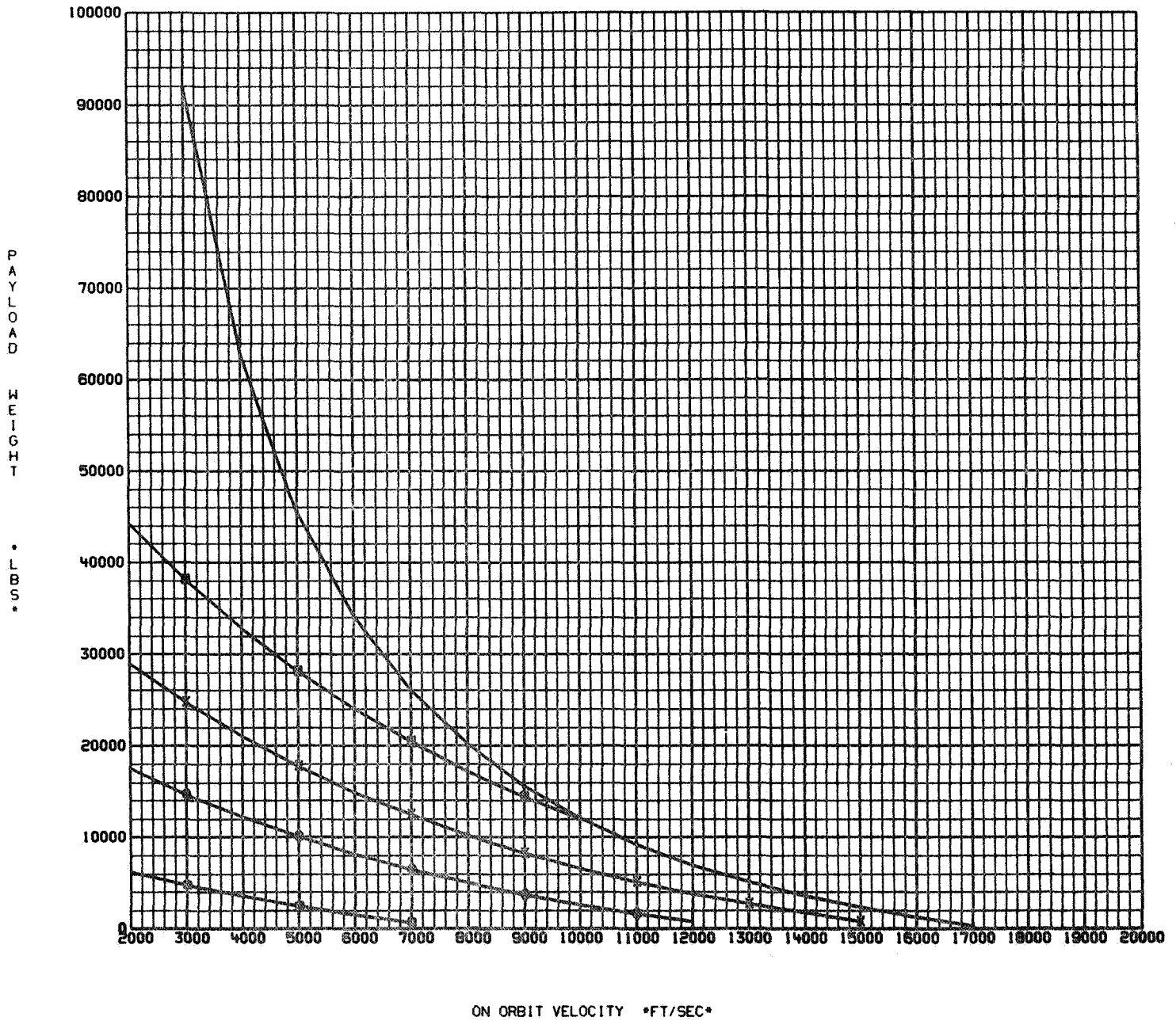
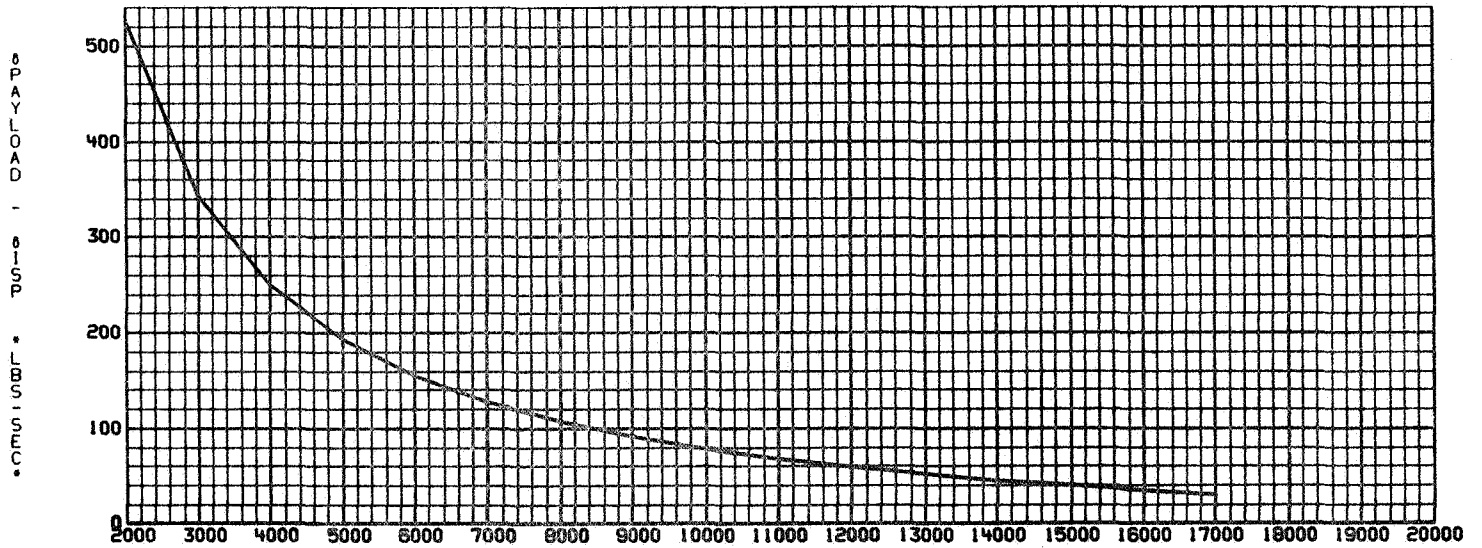


Figure 3-89

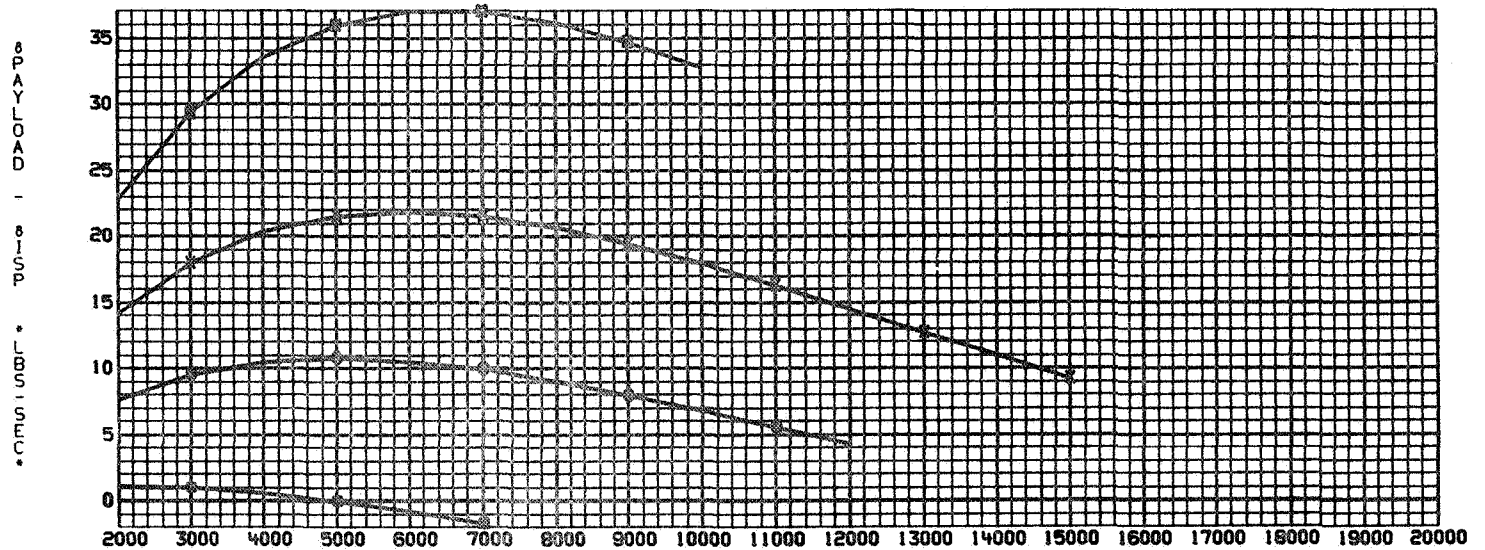
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



■ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 O = FIXED IGNITION 30000 LBS. M = FIXED IGNITION 65000 LBS.



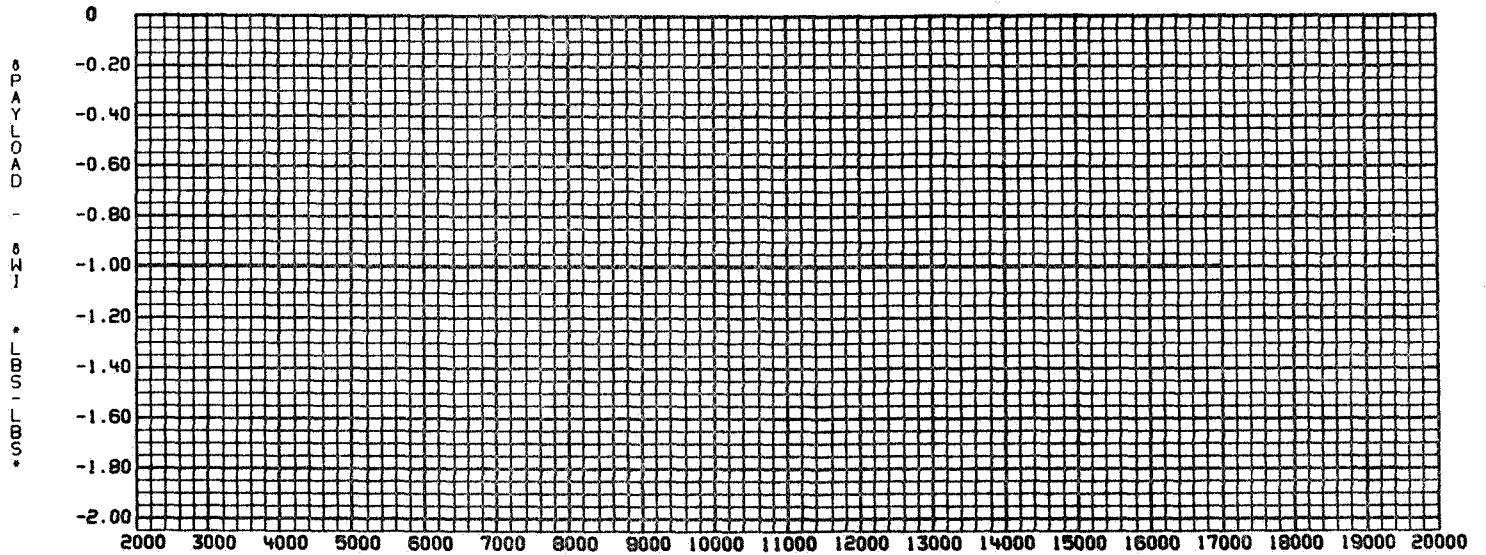
ON ORBIT VELOCITY *FT/SEC*

Figure 3-90

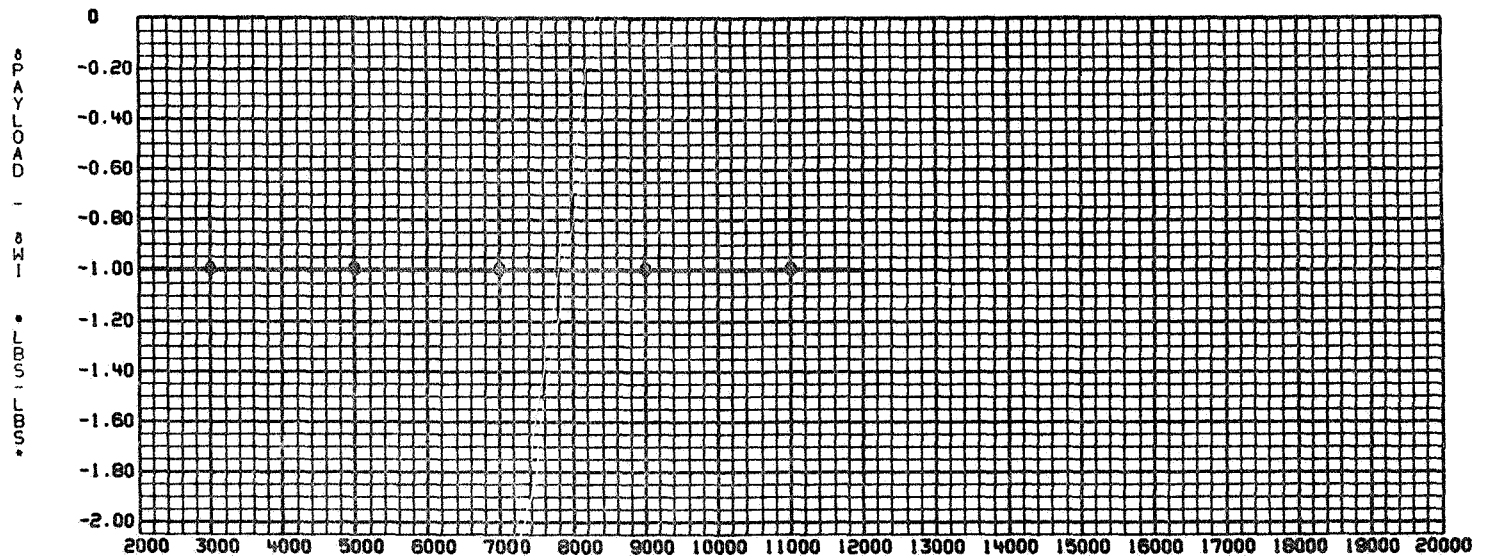
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



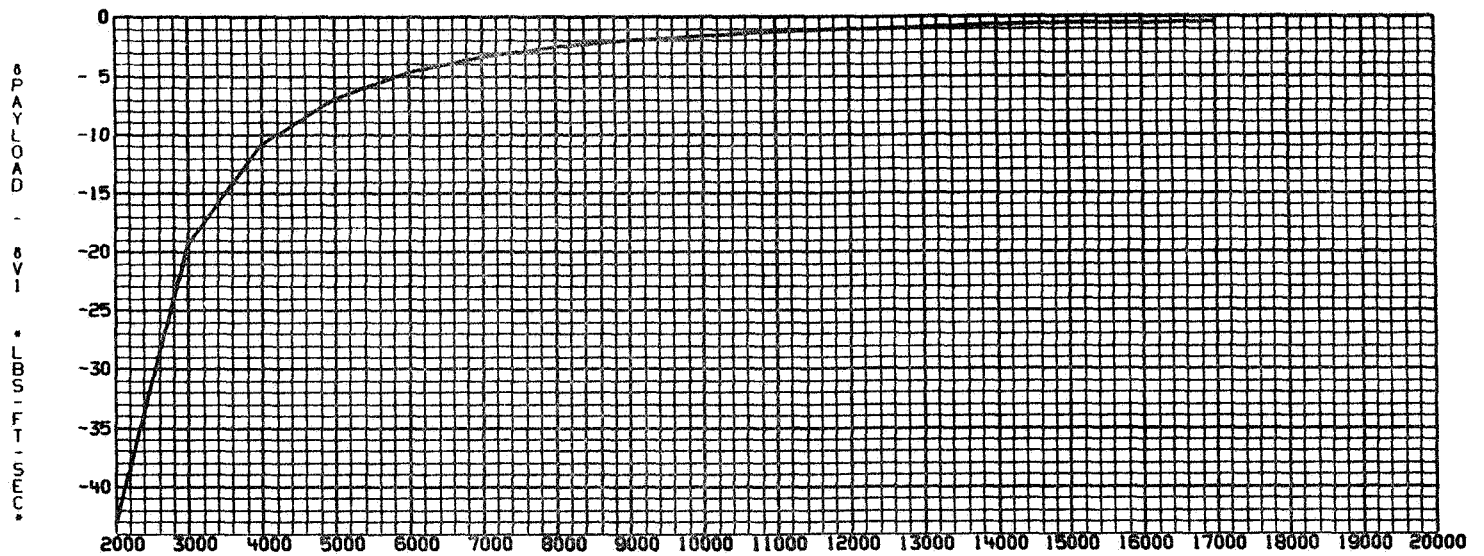
ON ORBIT VELOCITY *FT/SEC*

Figure 3-91

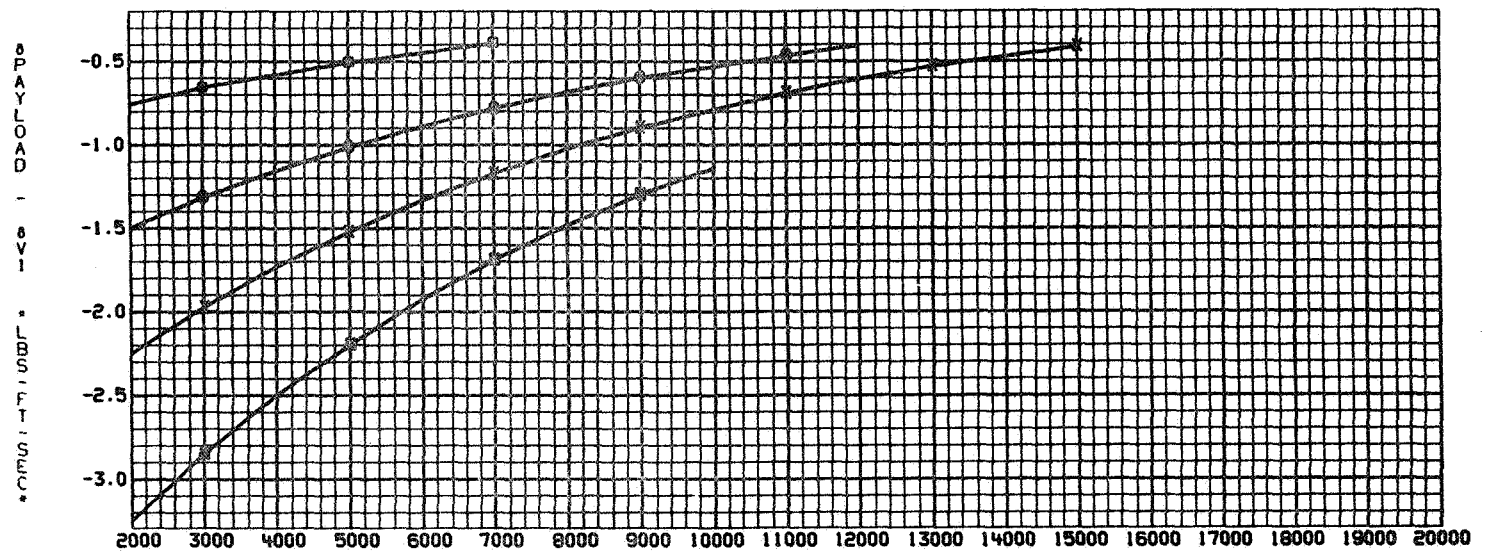
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



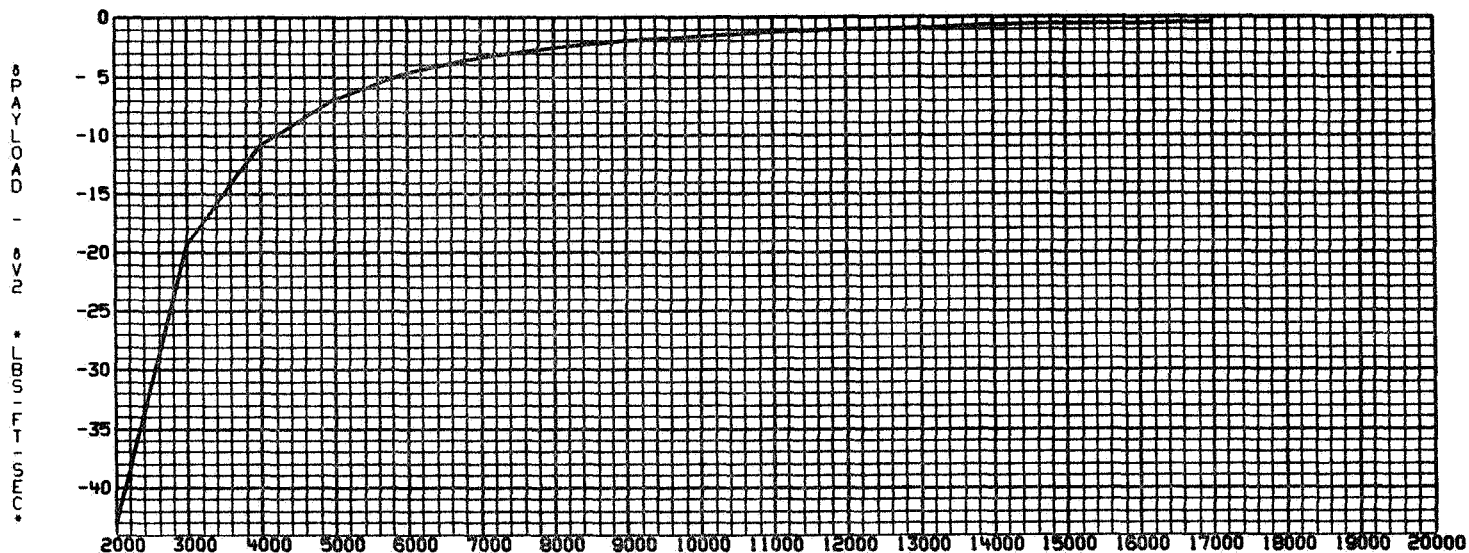
ON ORBIT VELOCITY *FT/SEC*

Figure 3-92

PAYLOAD DELIVERED

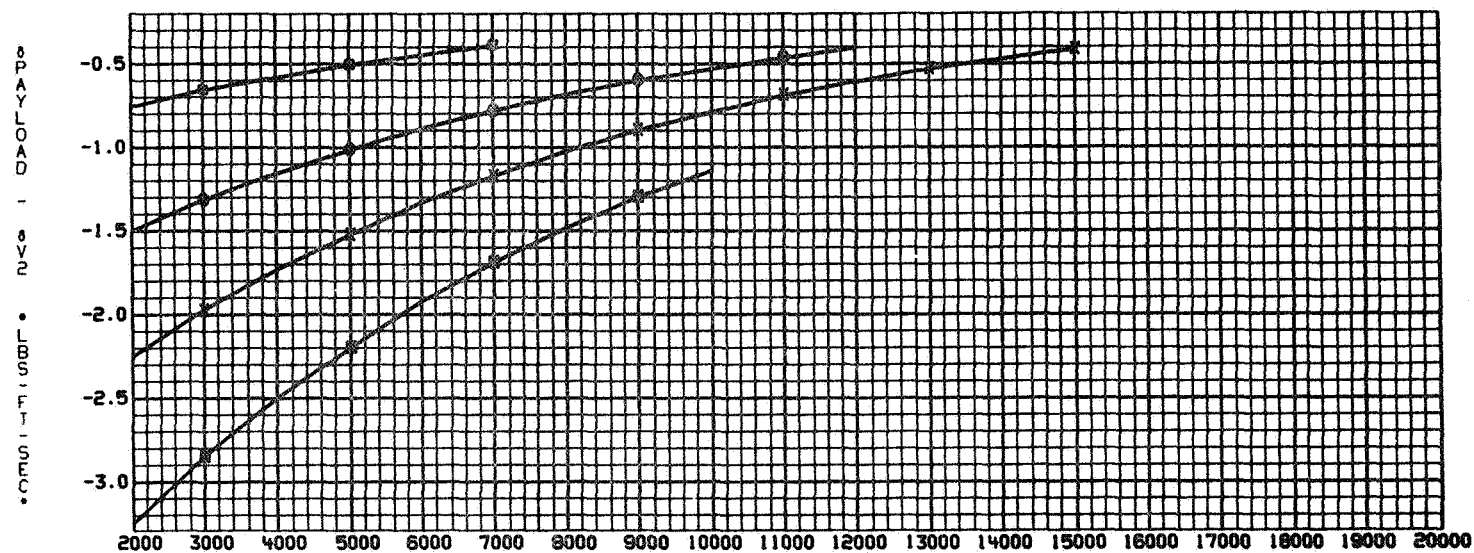
ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS.
○ = FIXED IGNITION 30000 LBS.

X = FIXED IGNITION 45000 LBS.
■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-93

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

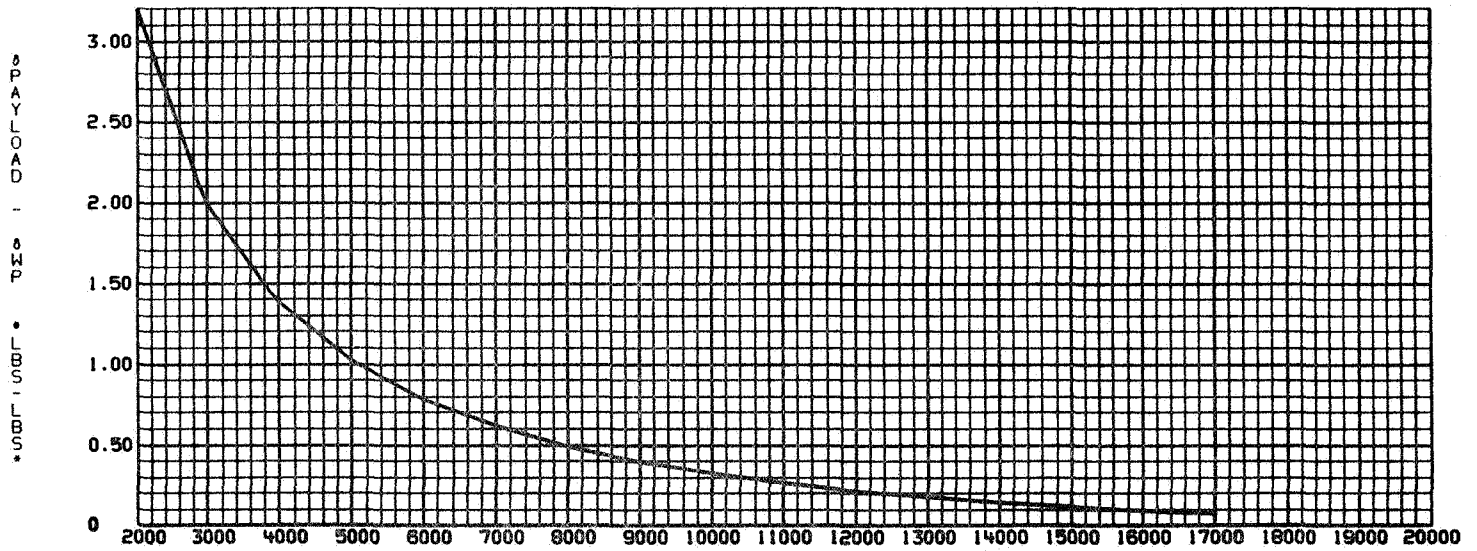


Figure 3-94

ALL FIXED IGNITION WEIGHTS

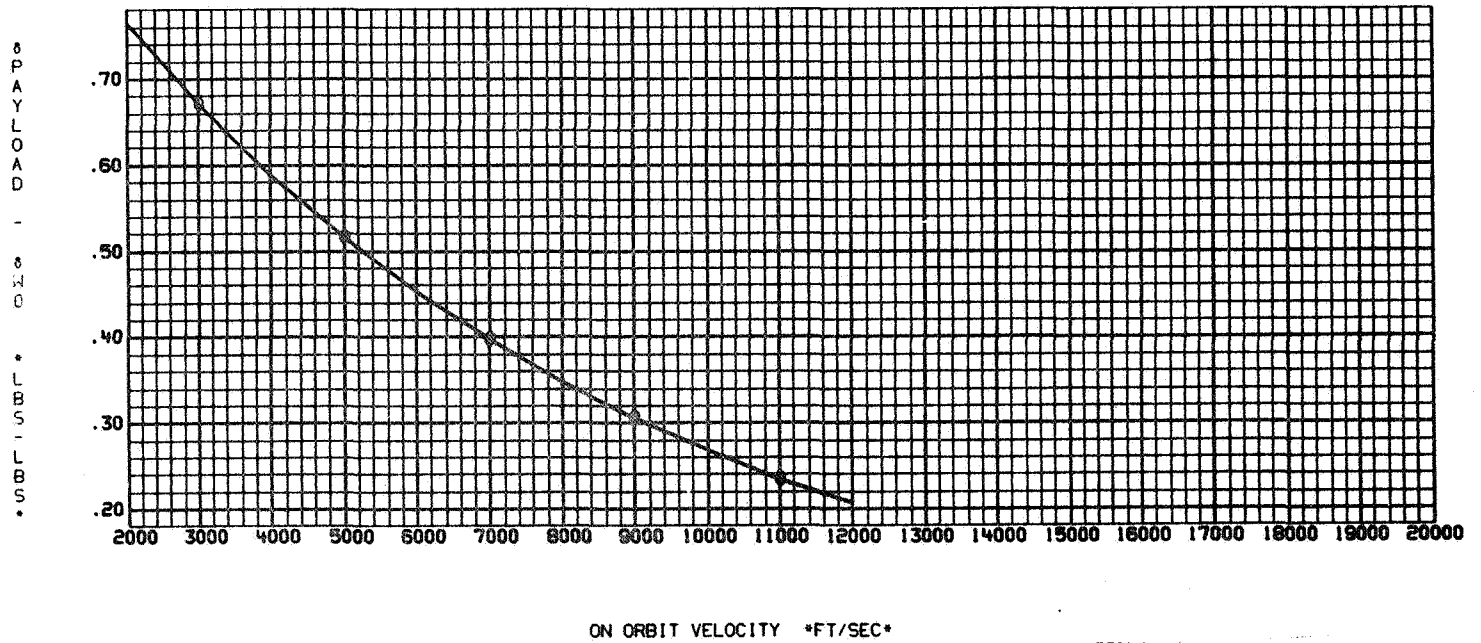


Figure 3-95

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

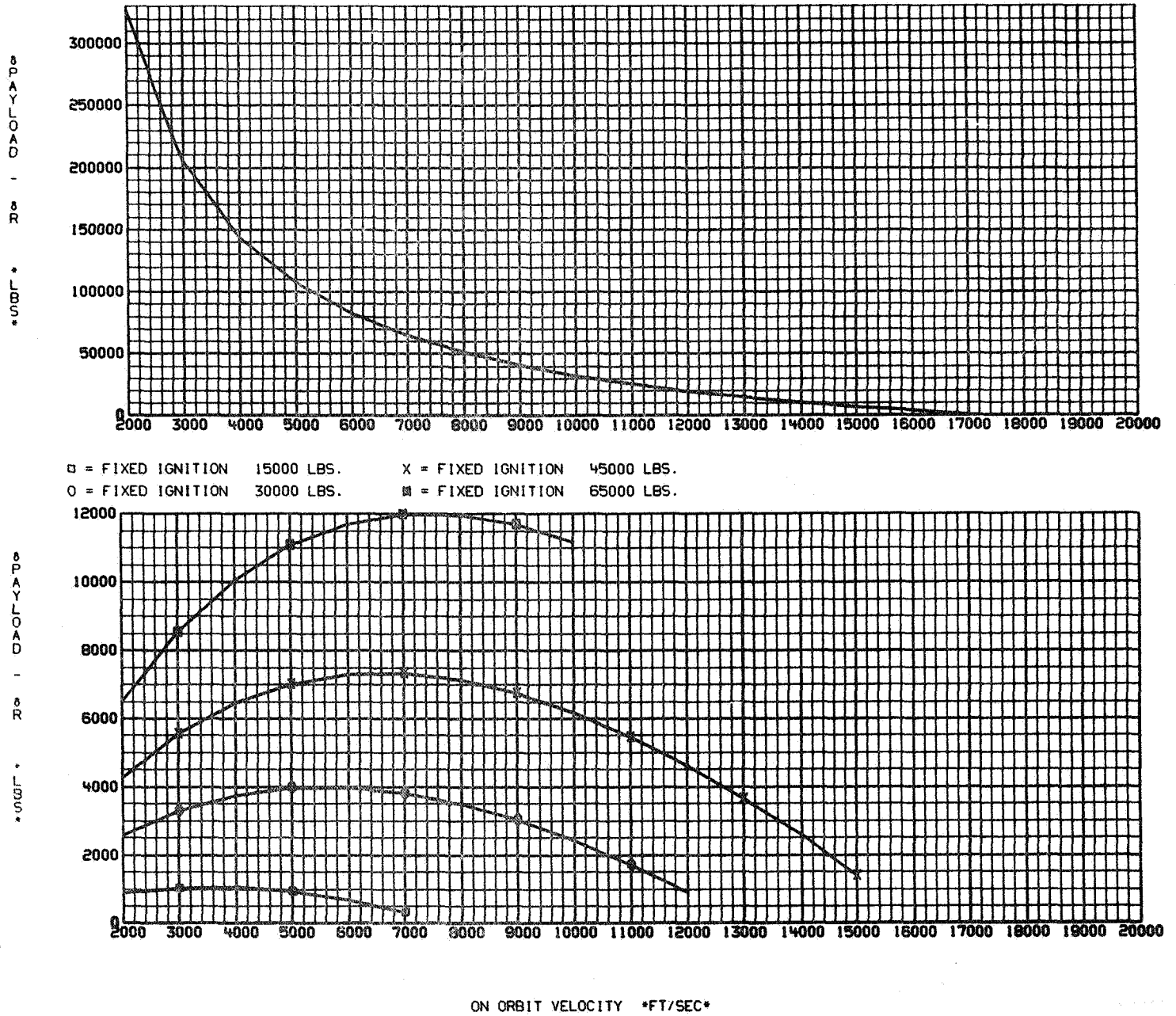


Figure 3-96

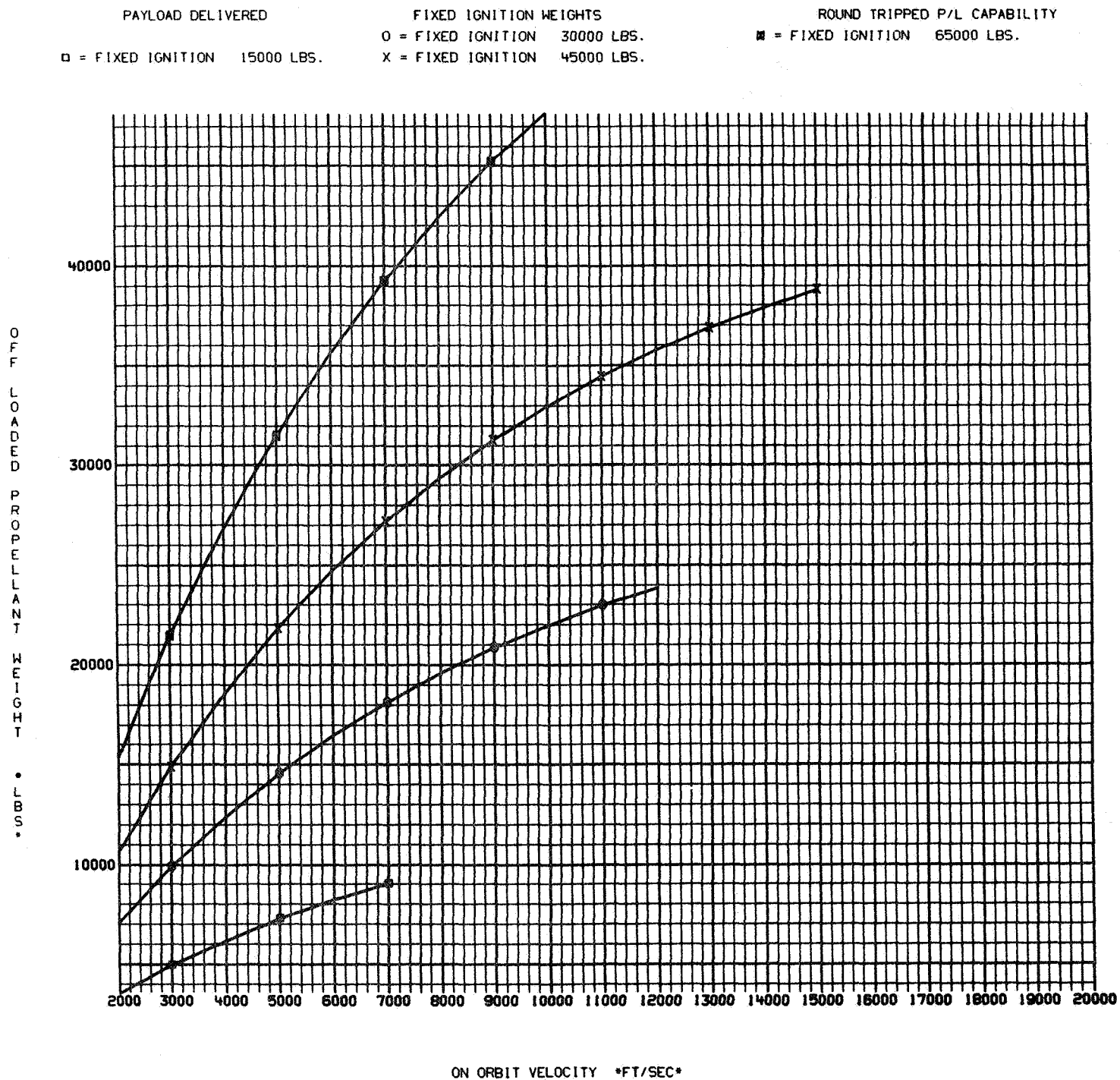


Figure 3-97

MODE 2

PAYLOAD RETURNED		47830 LBS. FIXED PROPELLANT WEIGHT	TUG - P/L RETRIEVAL CAPABILITY
• = FIXED PROPELLANT 47830 LBS.		O = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.		X = FIXED IGNITION 45000 LBS.	

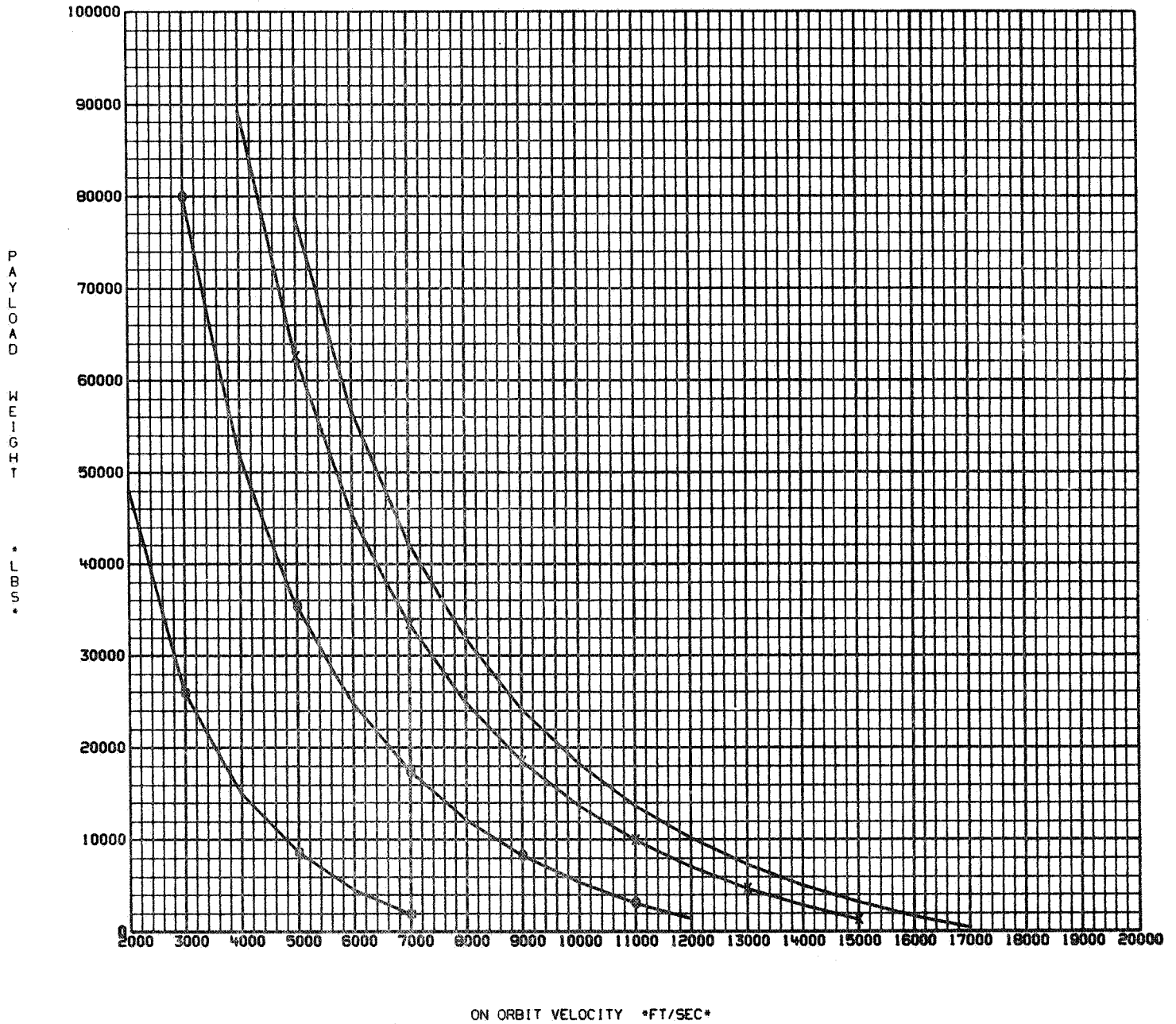
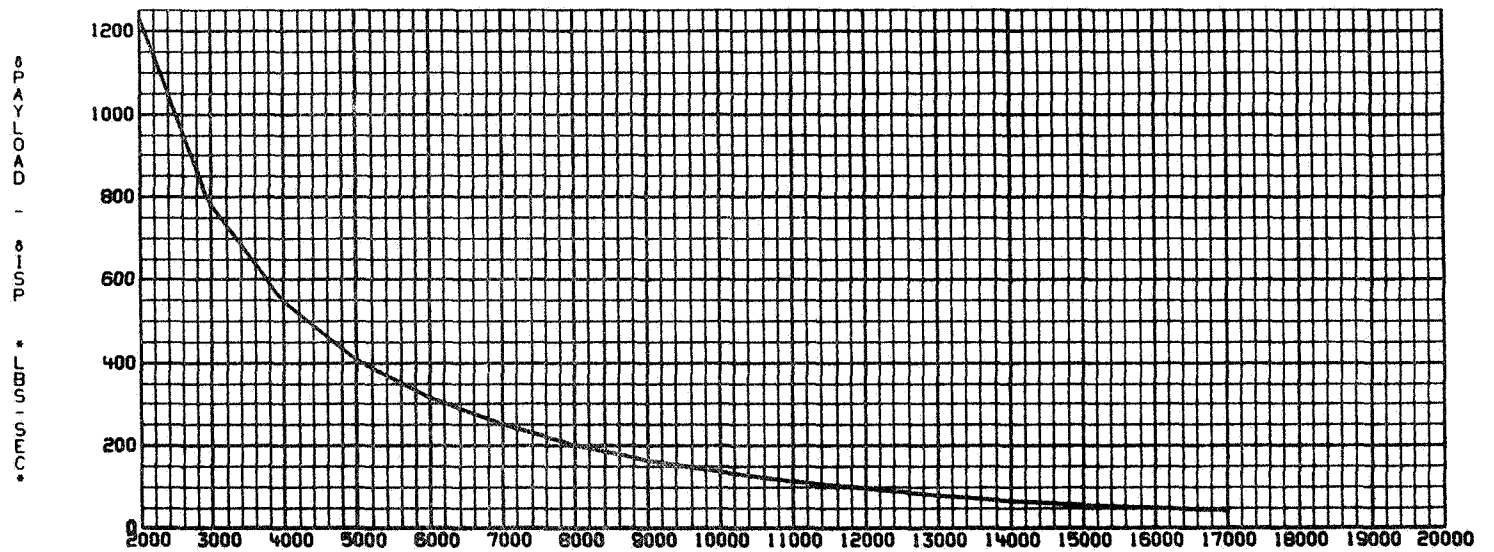


Figure 3-98

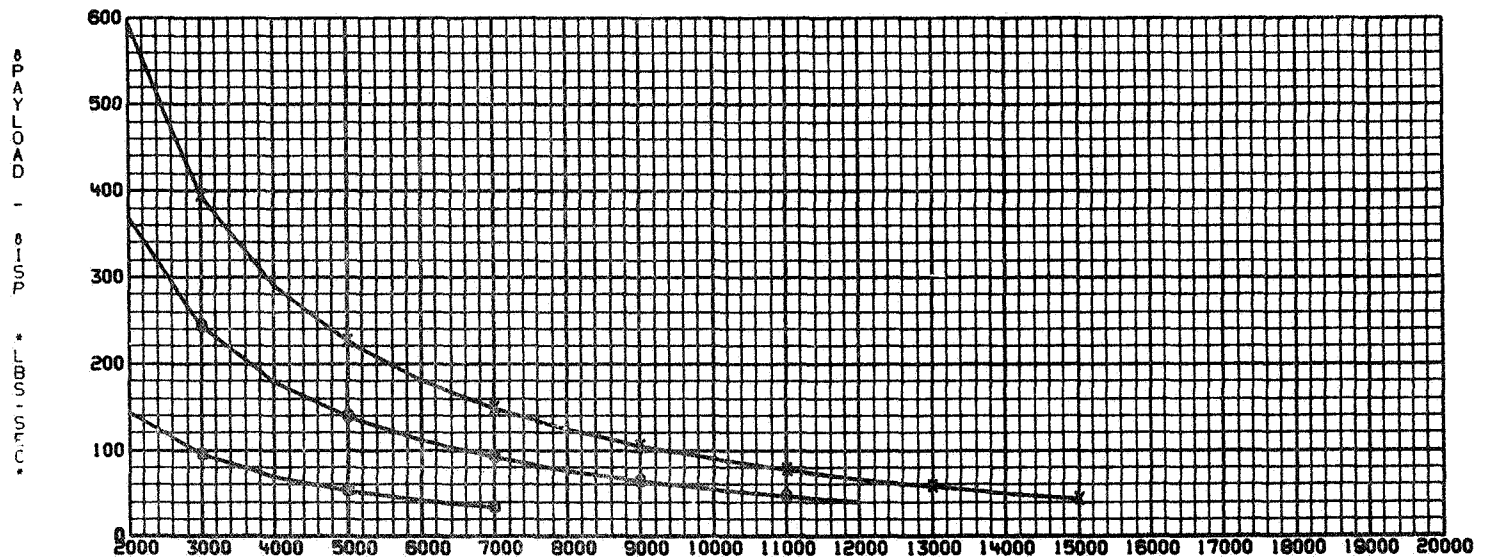
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ⊗ = FIXED IGNITION 65000 LBS.



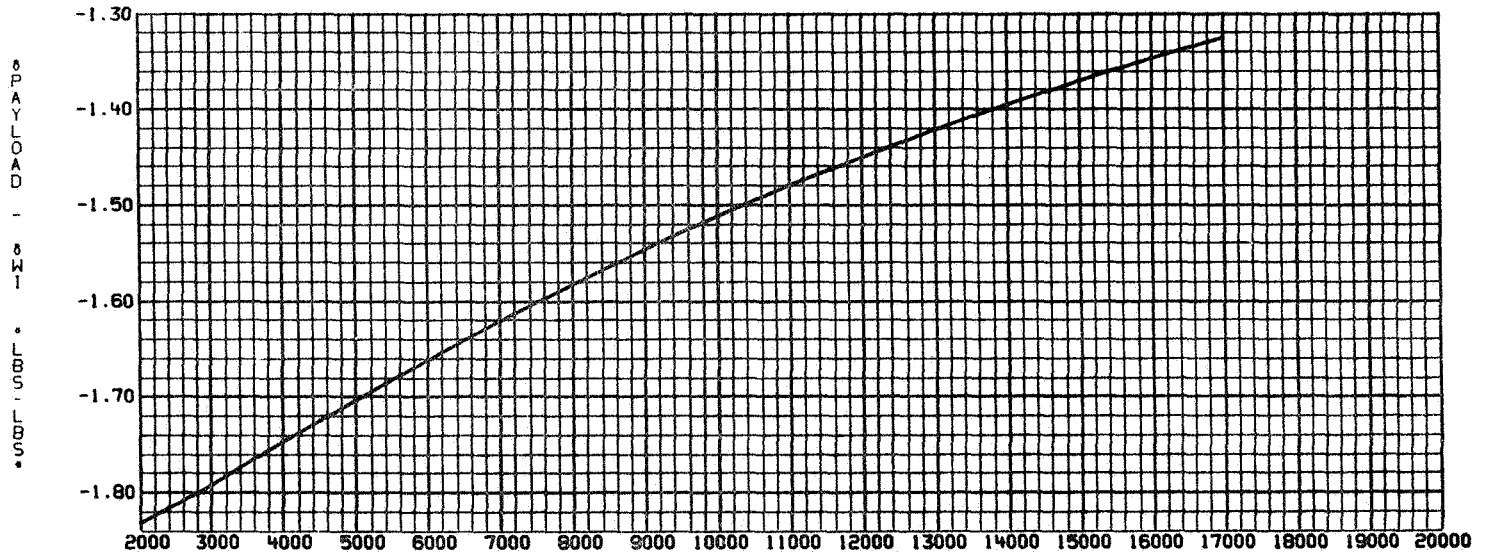
ON ORBIT VELOCITY *FT/SEC*

Figure 3-99

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS

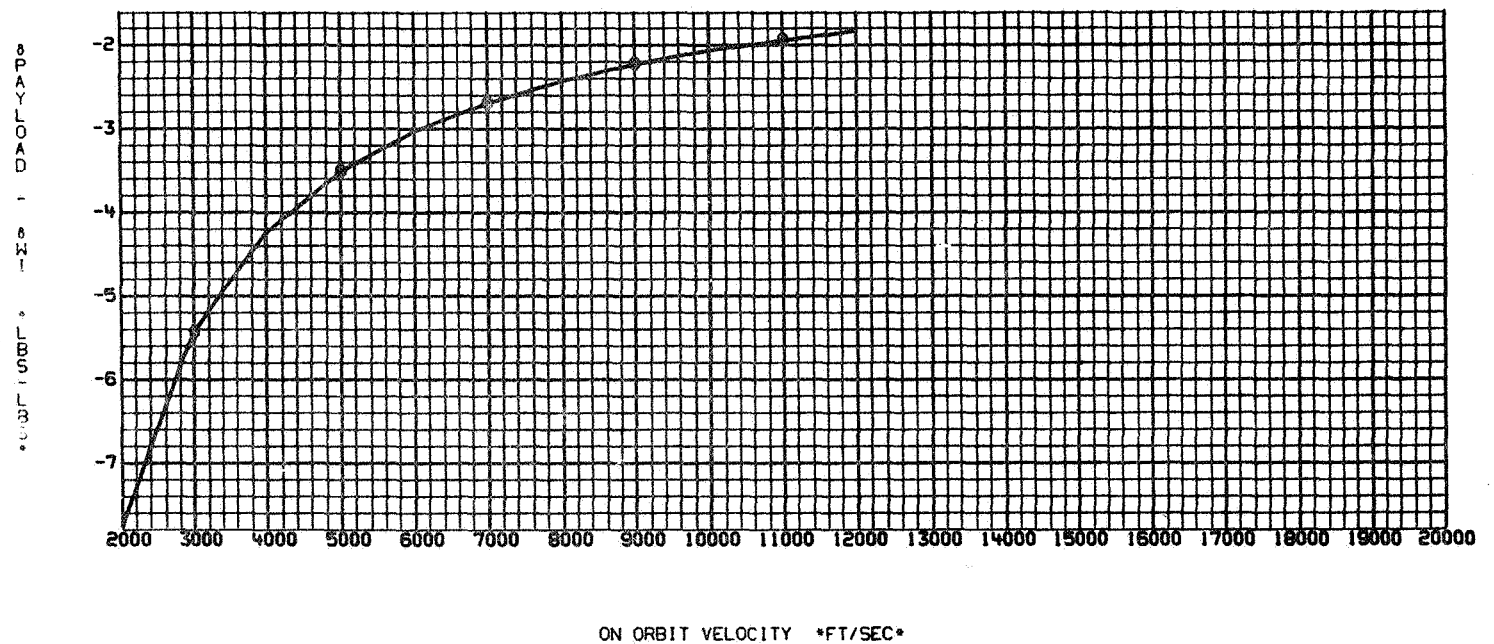
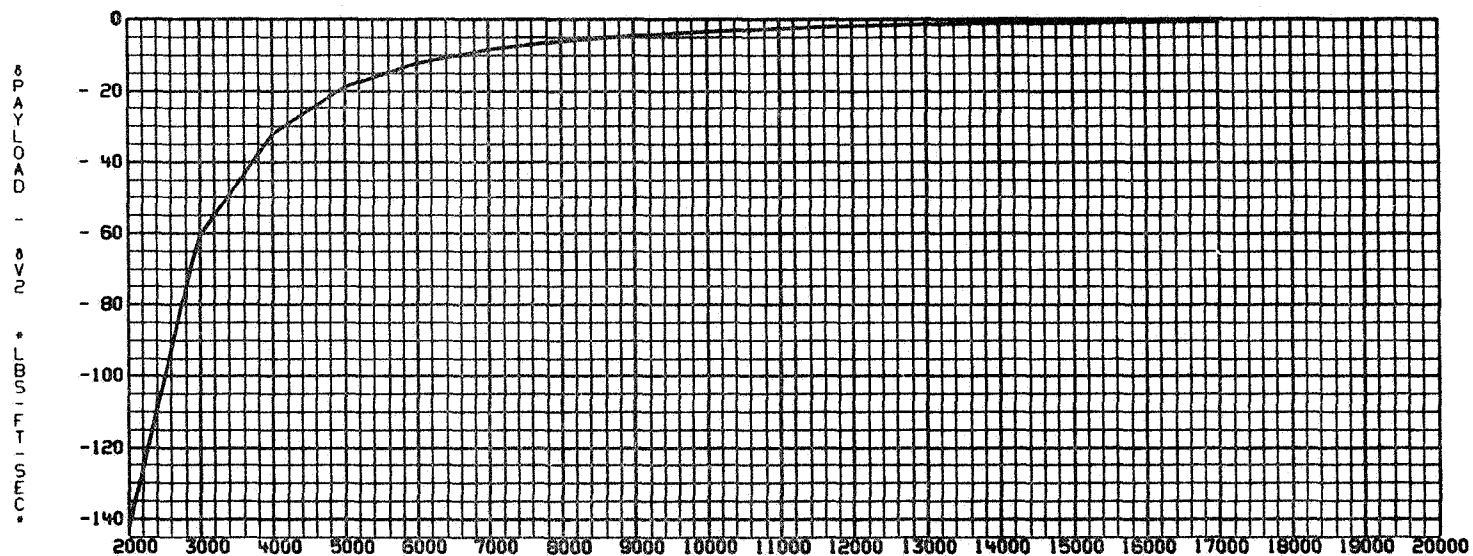


Figure 3-100

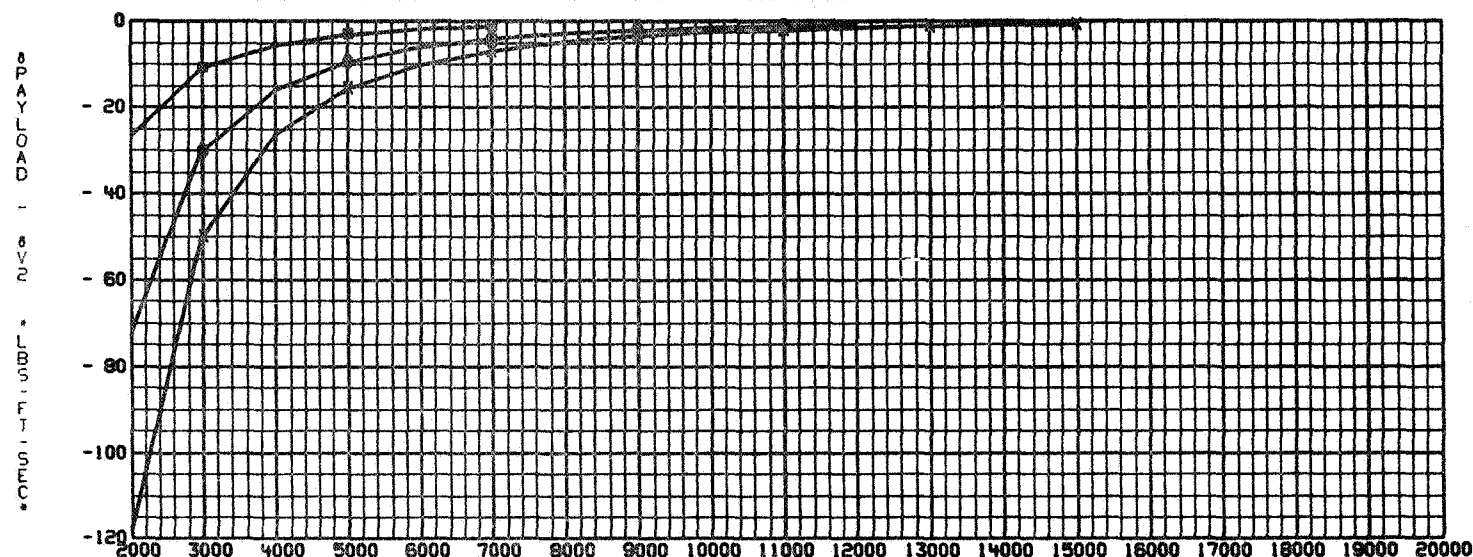
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-101

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

47830 LBS. FIXED PROPELLANT WEIGHT

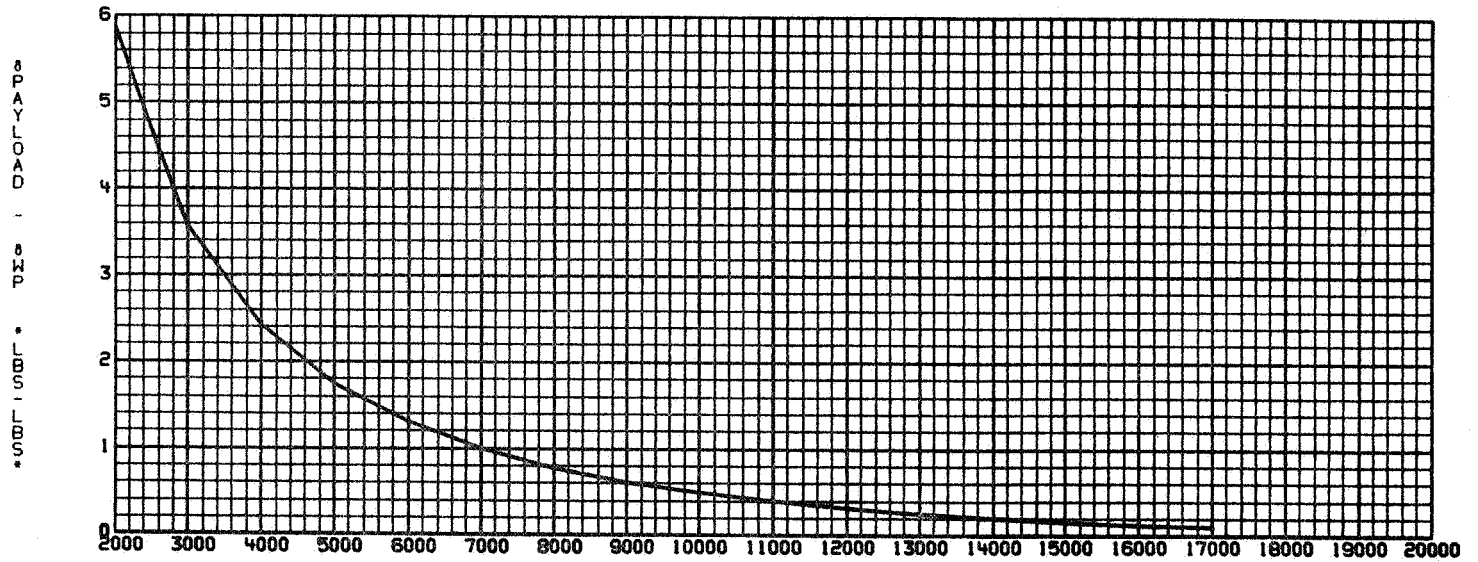


Figure 3-102

ALL FIXED IGNITION WEIGHTS

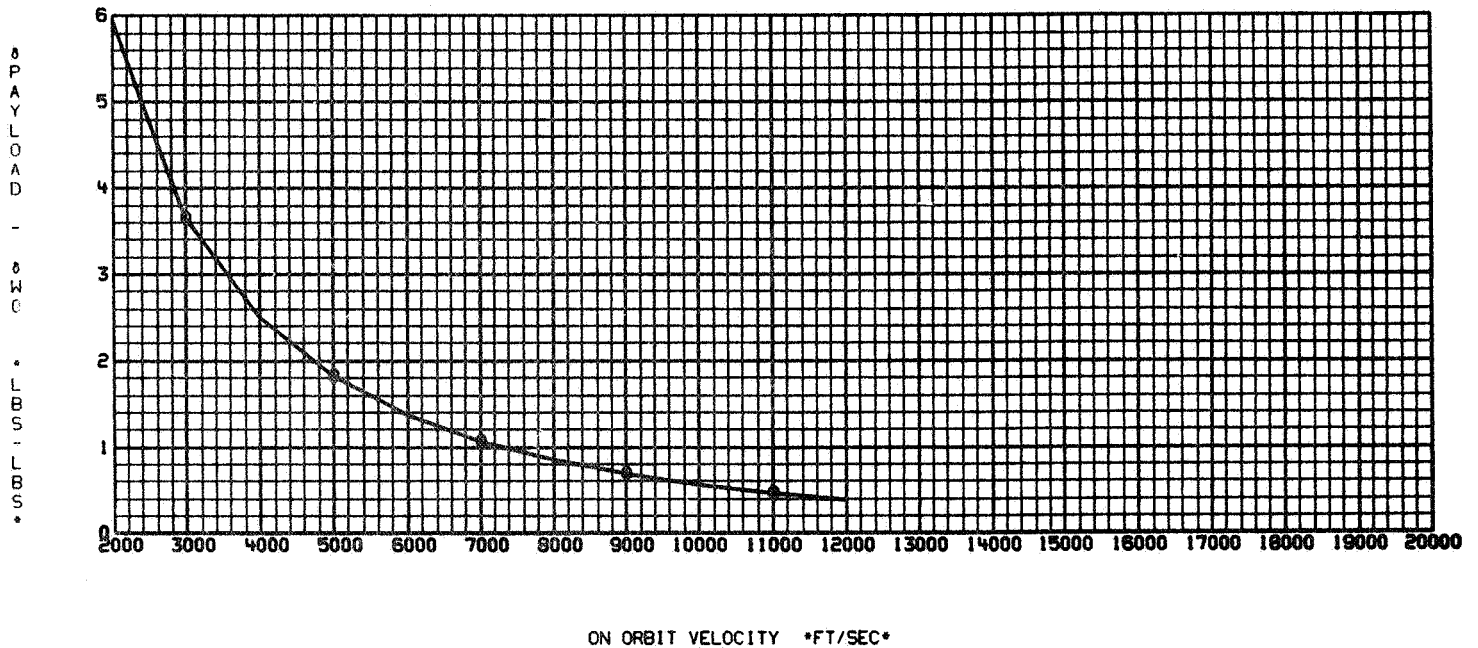


Figure 3-103

NOTE

Offloaded propellant
in Mode 2 is not
a function of ΔV

Figure 3-104

MODE 3

PAYLOAD DELIVERED
 • = FIXED PROPELLANT 47830 LBS.
 □ = FIXED IGNITION 15000 LBS.
 47830 LBS. FIXED PROPELLANT WEIGHT
 O = FIXED IGNITION 30000 LBS.
 X = FIXED IGNITION 45000 LBS.
 EXPENDABLE P/L ** REUSEABLE TUG
 ■ = FIXED IGNITION 65000 LBS.

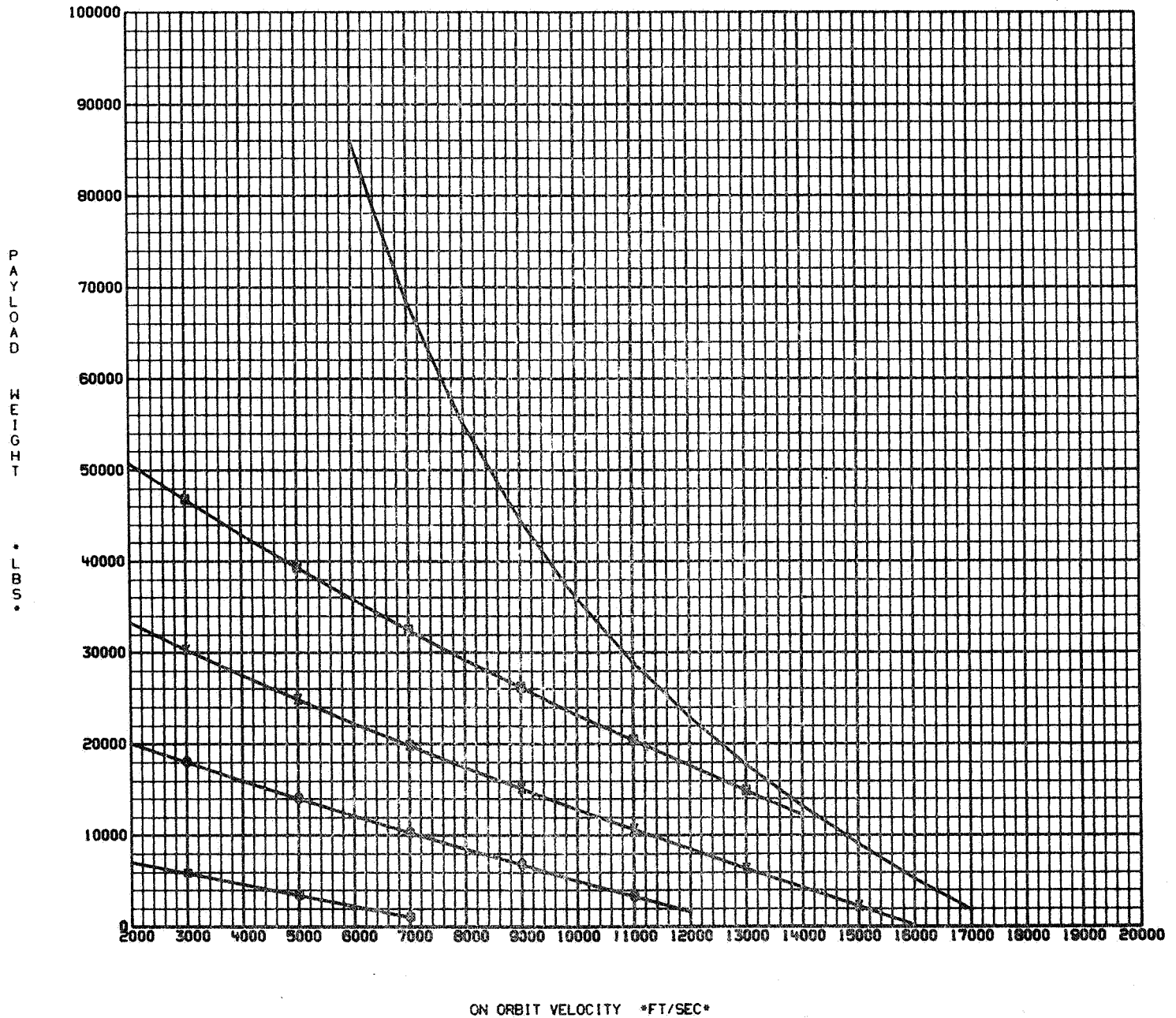
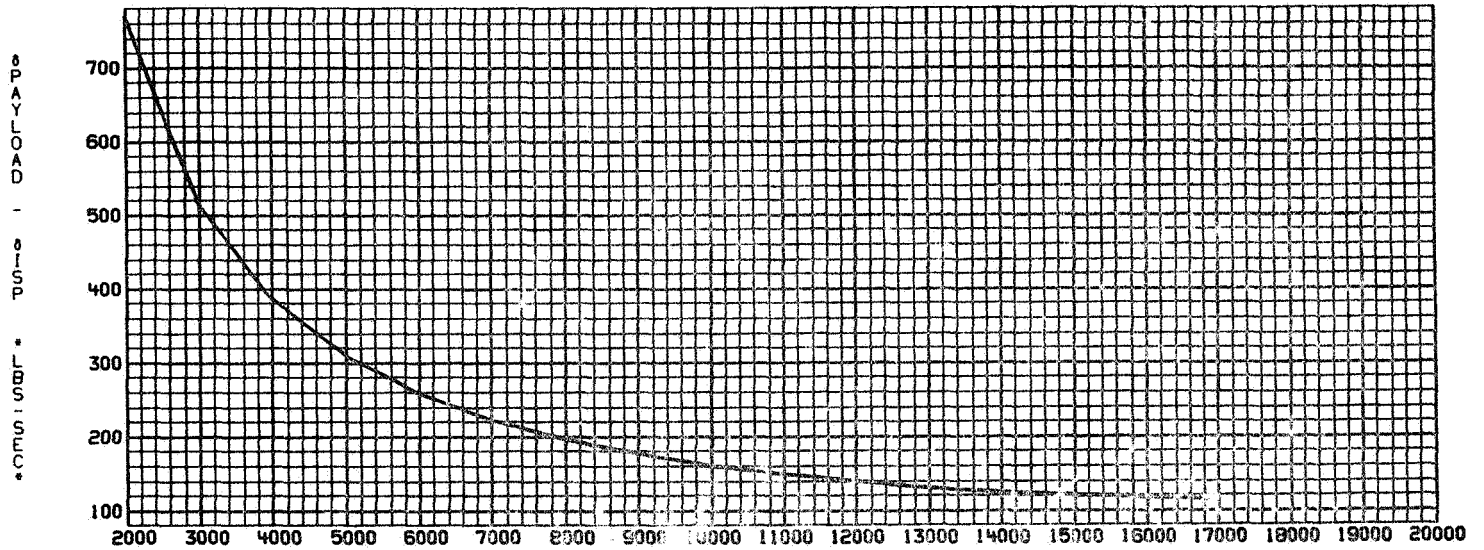


Figure 3-105

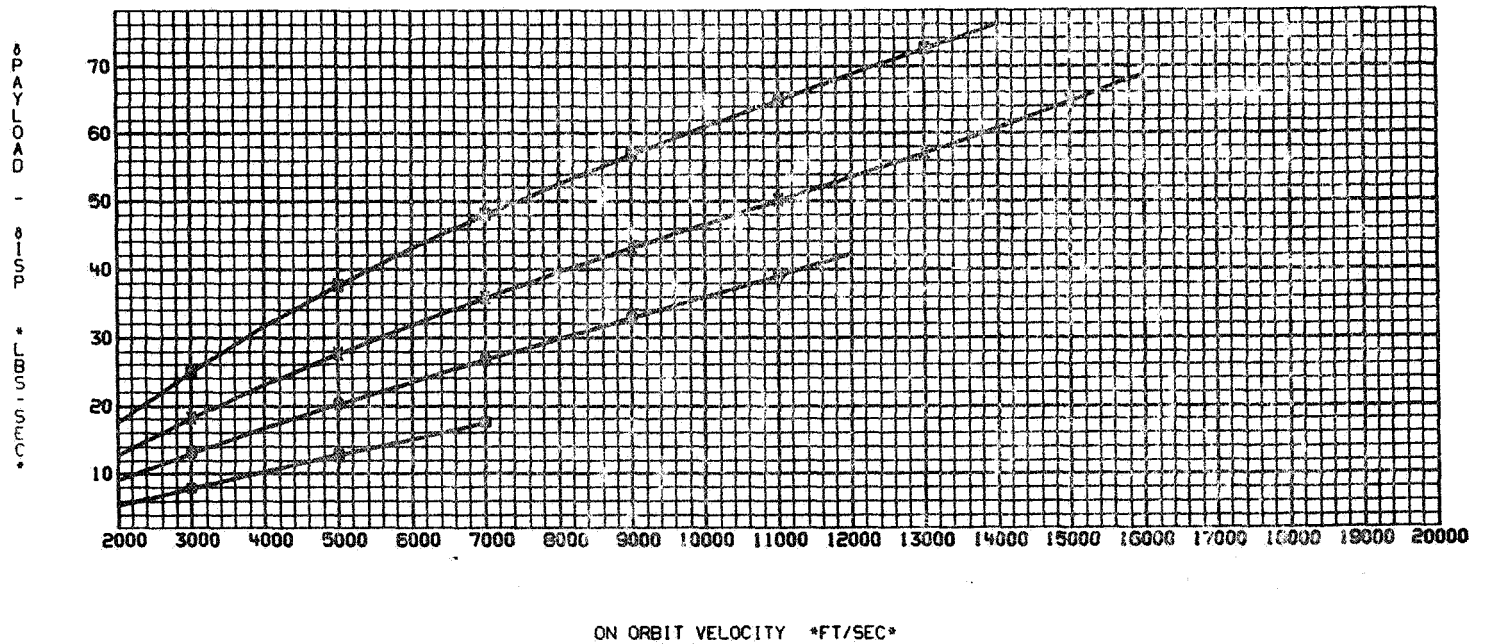
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



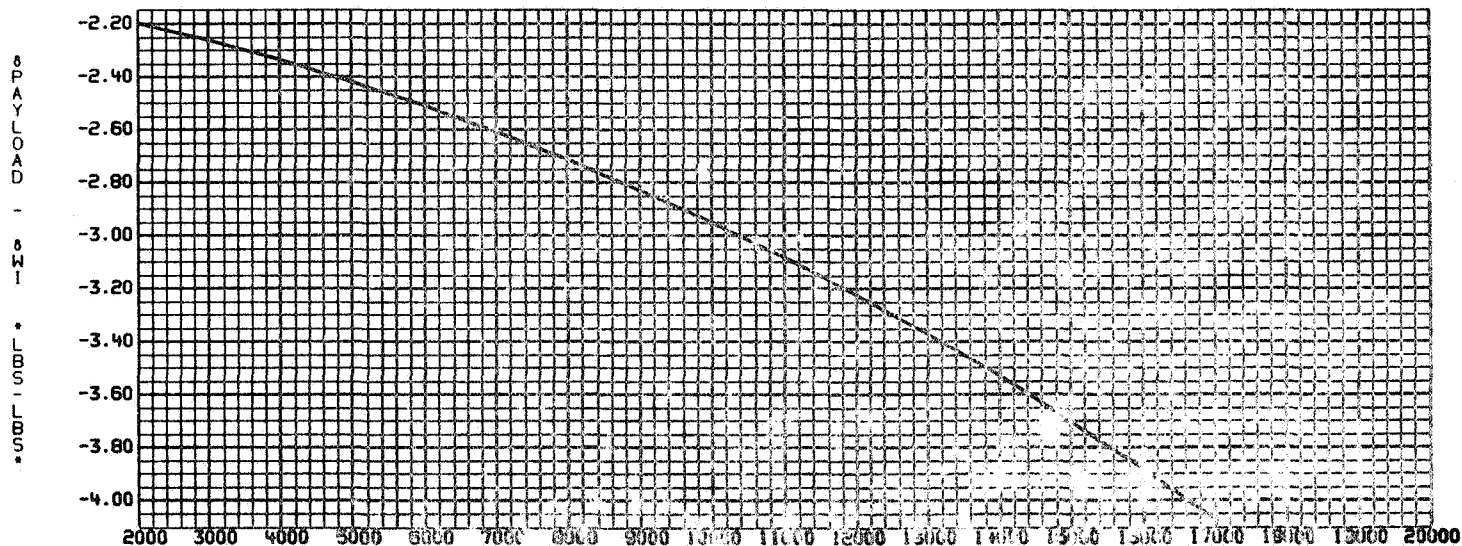
ON ORBIT VELOCITY *FT/SEC*

Figure 3-106

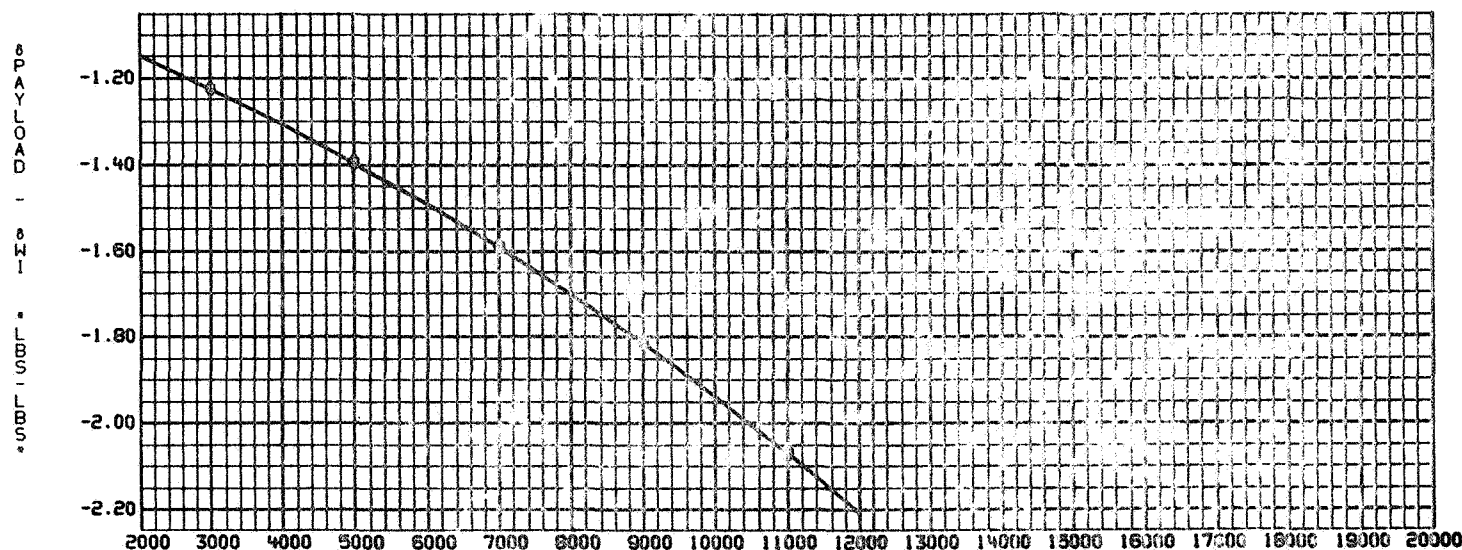
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



ON ORBIT VELOCITY *FT/SEC*

Figure 3-107

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT

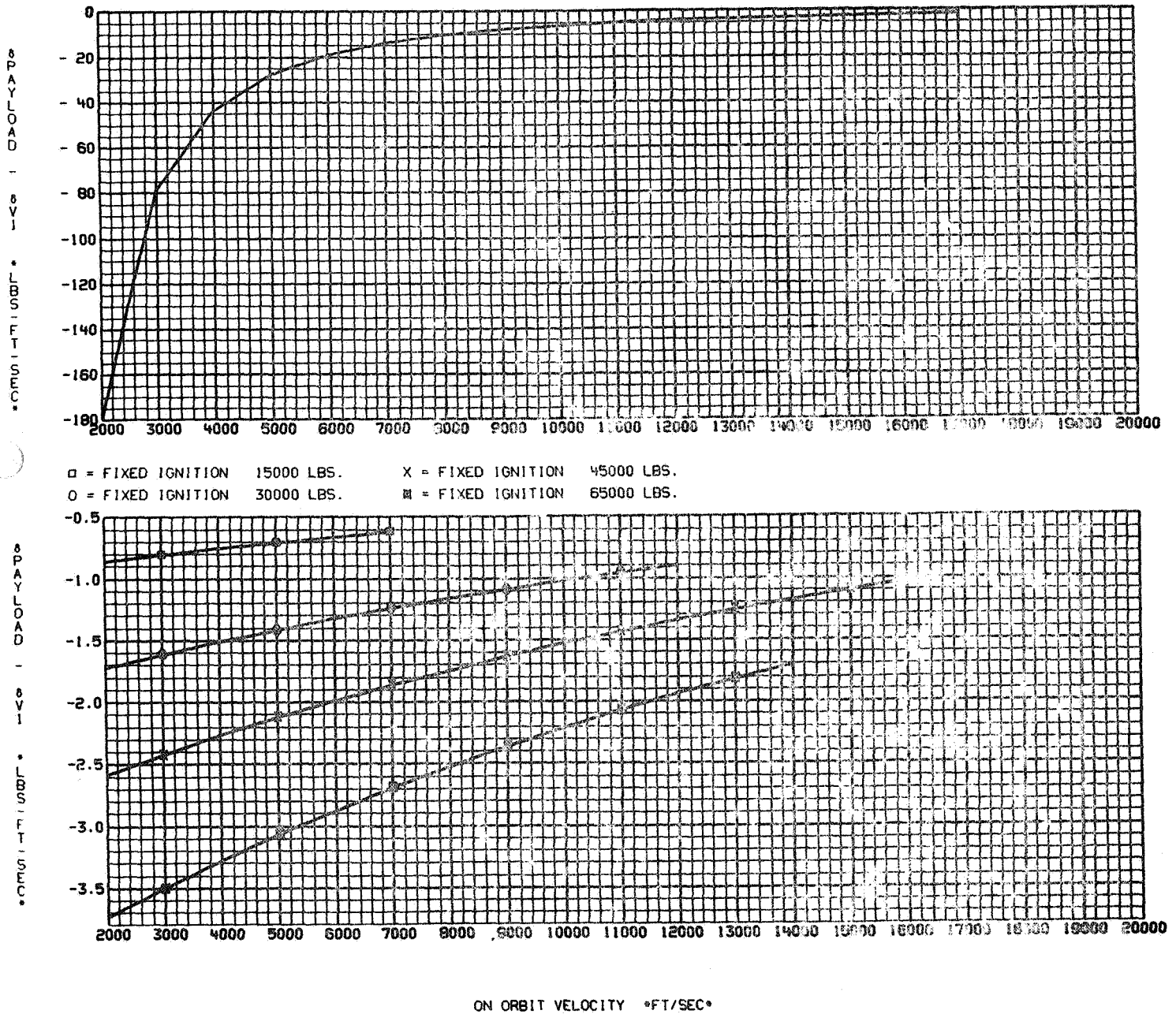


Figure 3-108

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

47830 LBS. FIXED PROPELLANT WEIGHT

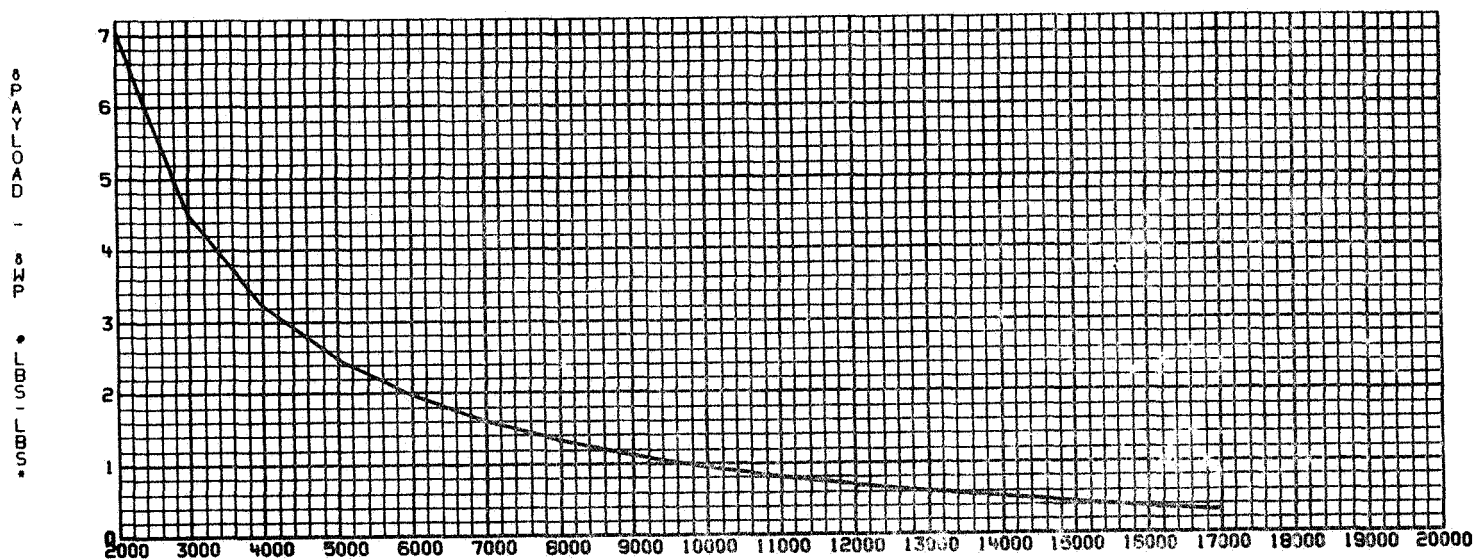


Figure 3-109

ALL FIXED IGNITION WEIGHTS

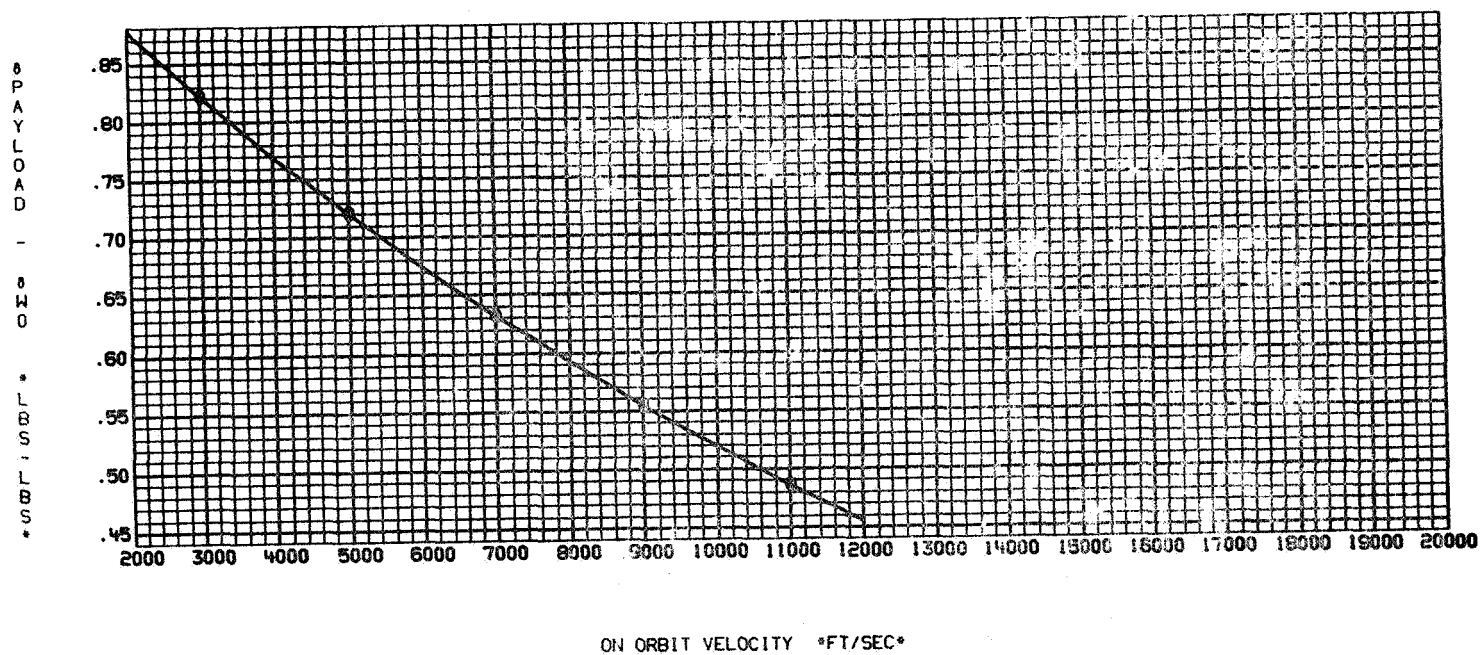


Figure 3-110

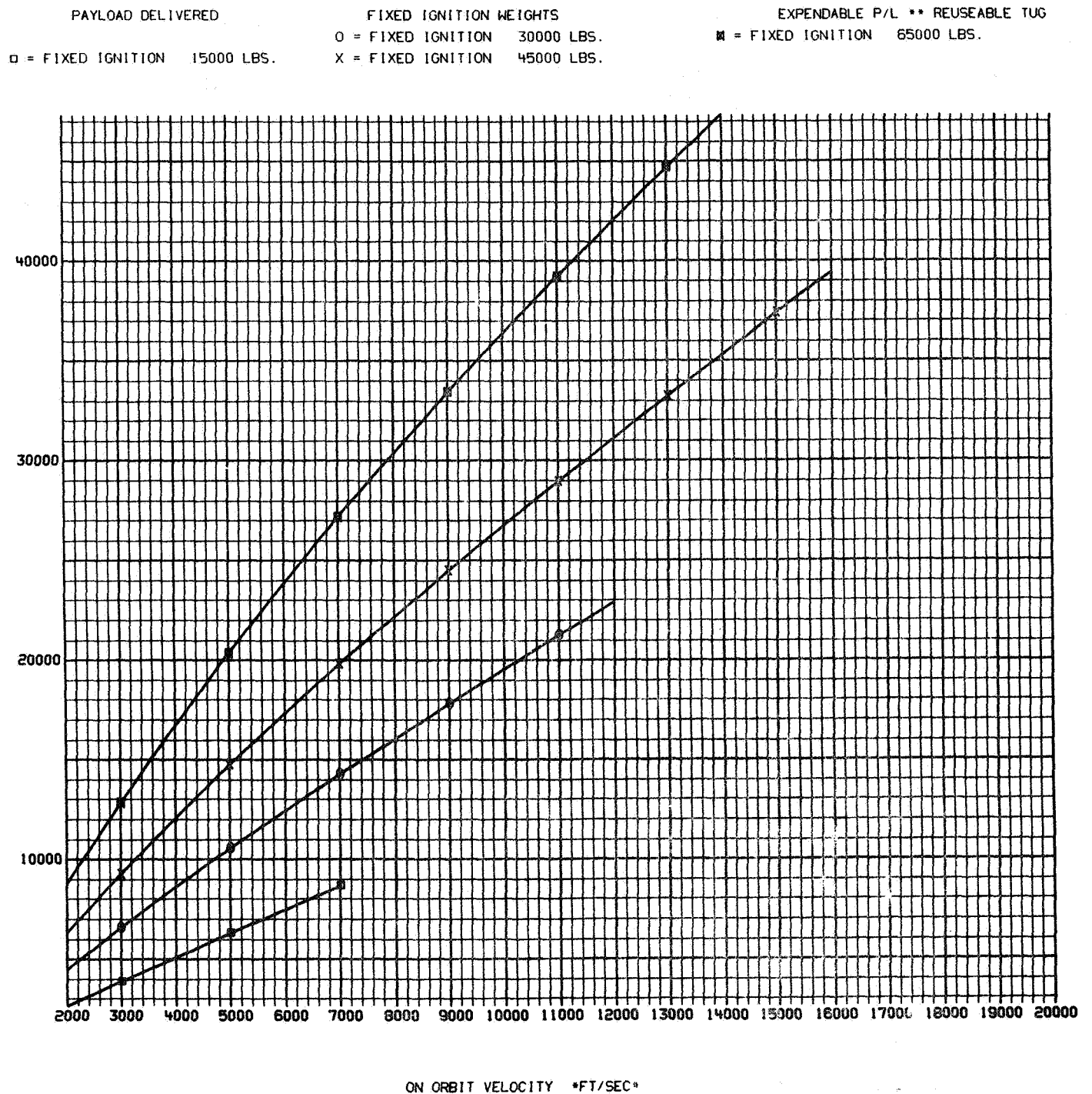


Figure 3-111

MODE 4

PAYLOAD DELIVERED	47830 LBS. FIXED PROPELLANT WEIGHT	EXPENDABLE TUG AND P/L
• = FIXED PROPELLANT 47830 LBS.	O = FIXED IGNITION 30000 LBS.	M = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.	X = FIXED IGNITION 45000 LBS.	

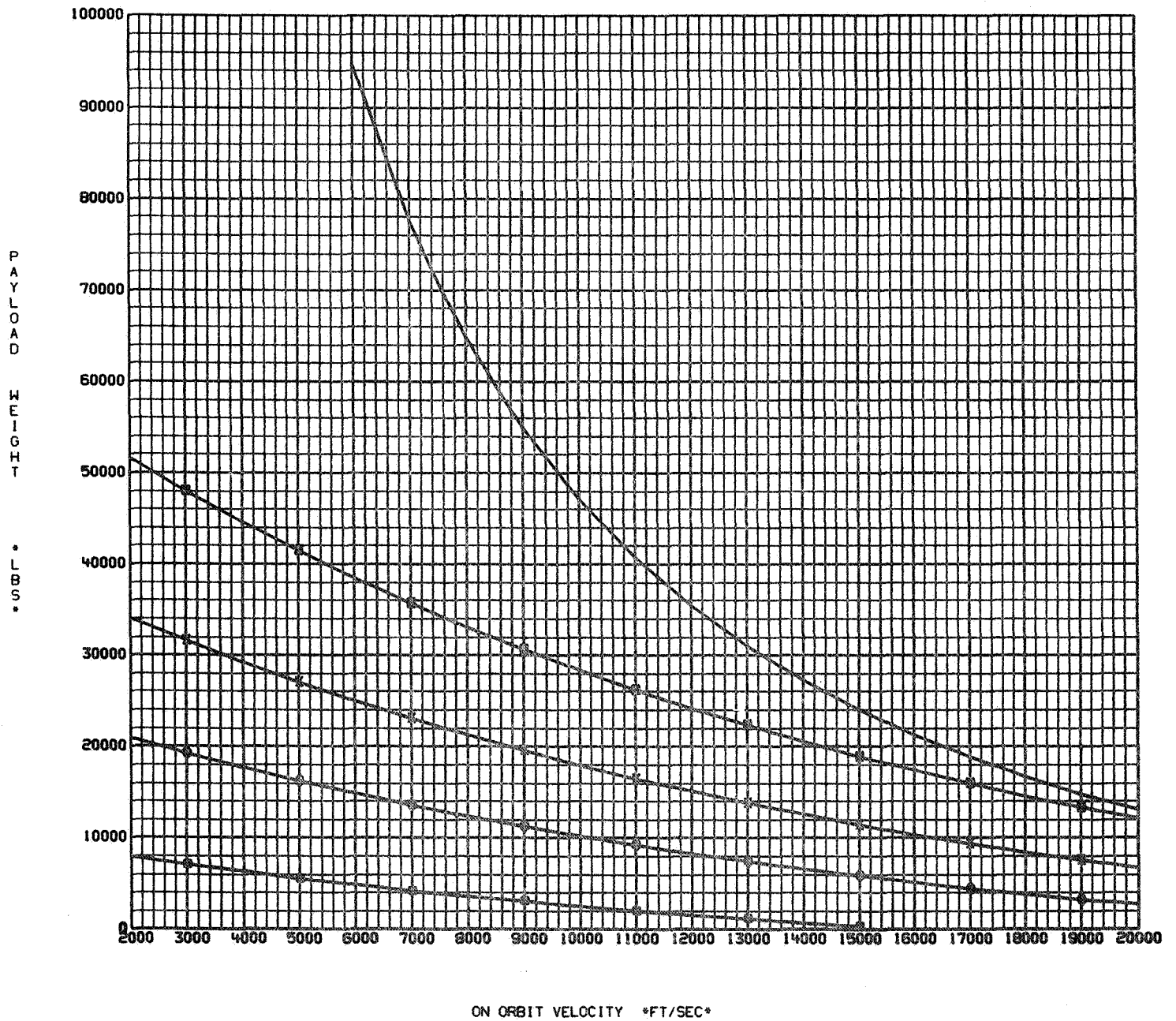


Figure 3-112

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

47830 LBS. FIXED PROPELLANT WEIGHT

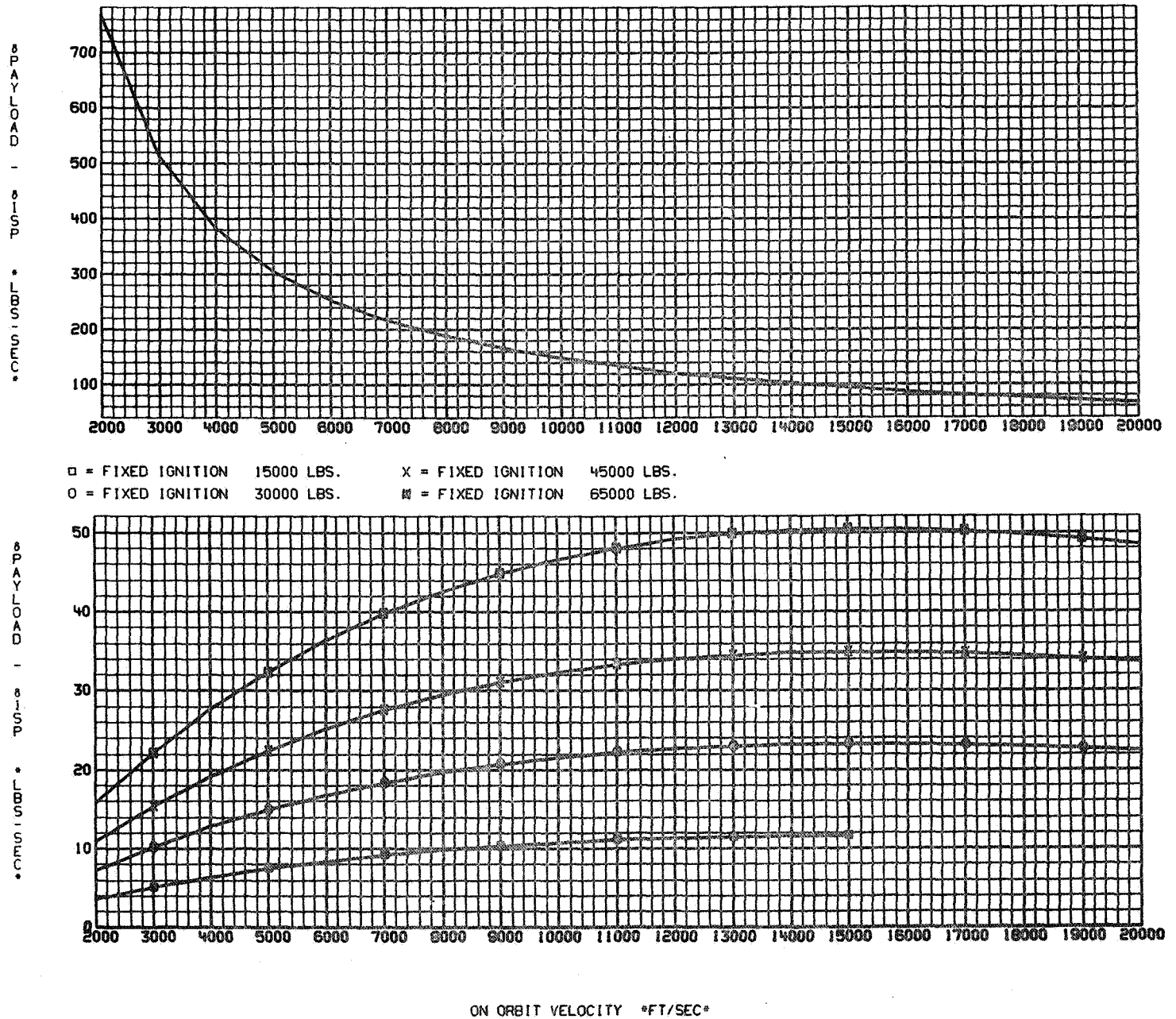
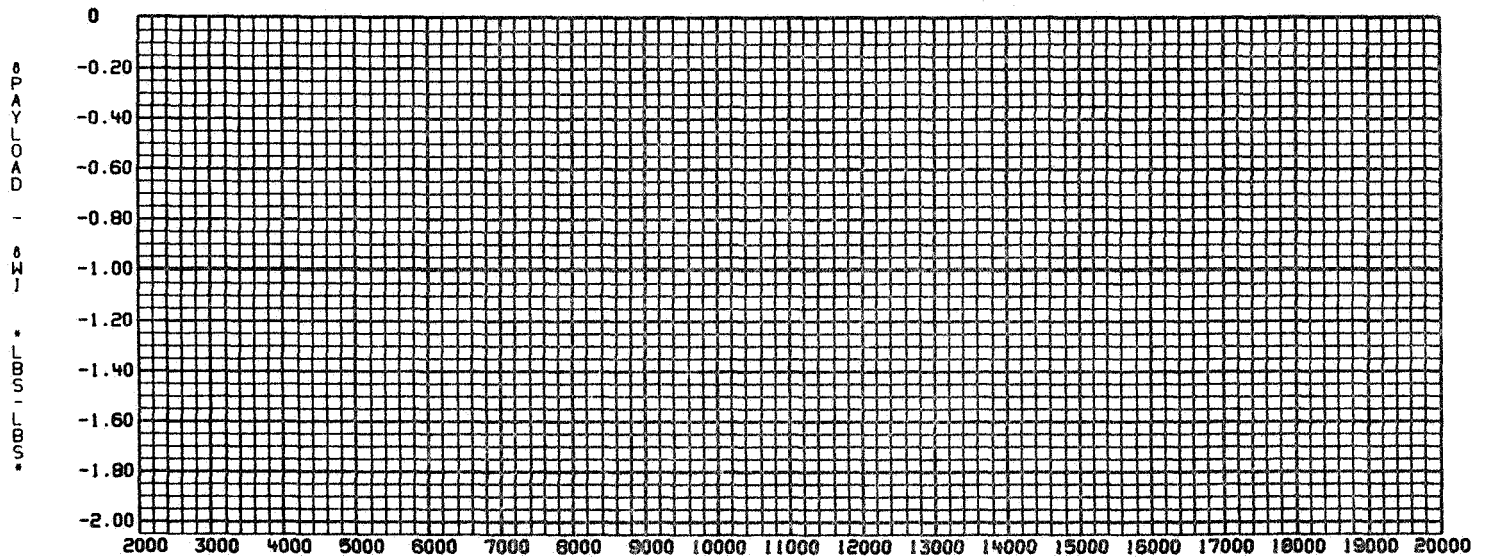


Figure 3-113

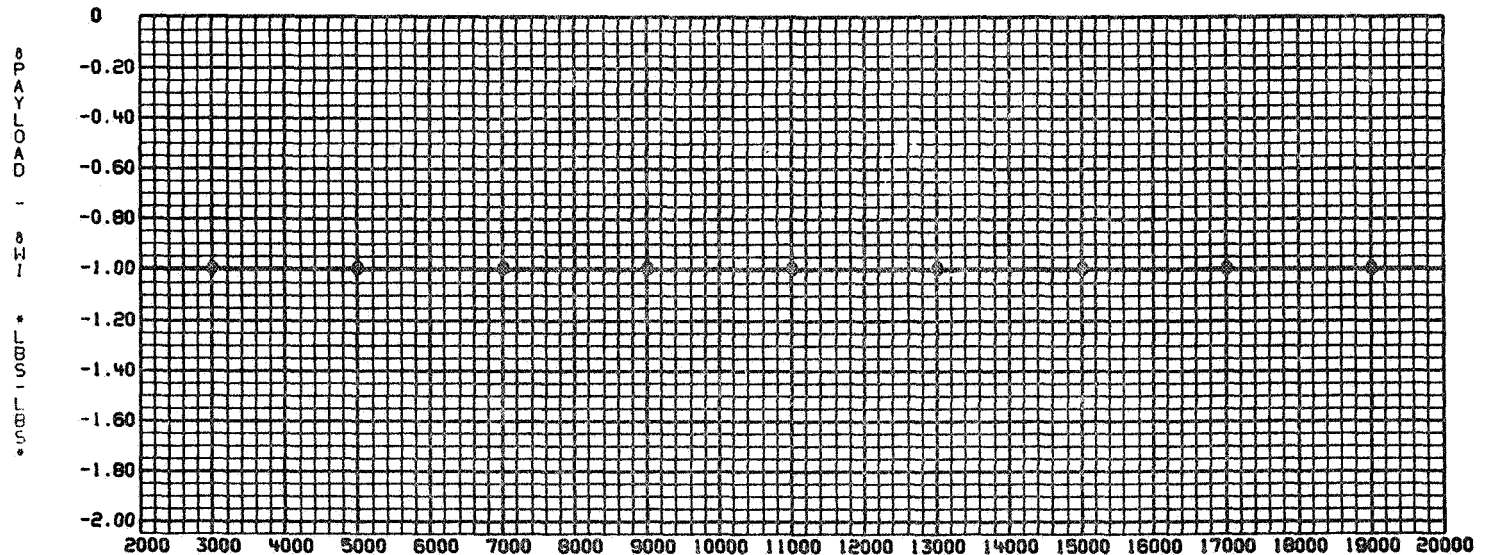
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

47830 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



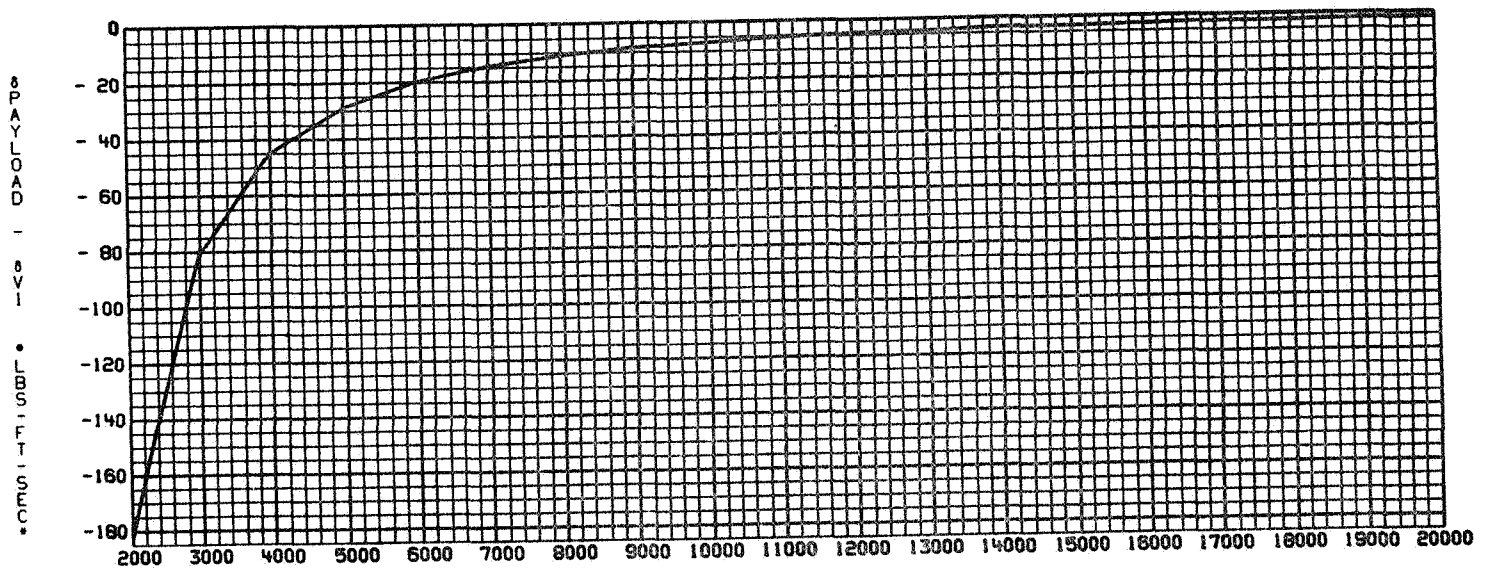
ON ORBIT VELOCITY *FT/SEC*

Figure 3-114

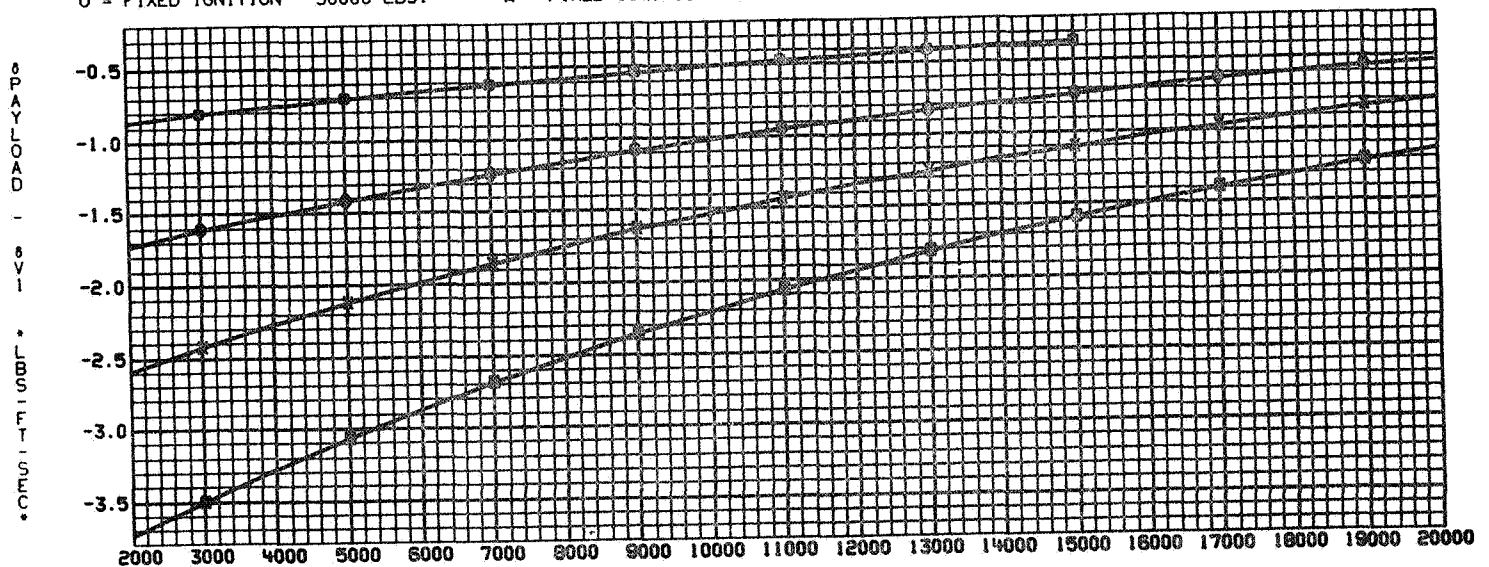
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

47830 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
O = FIXED IGNITION 30000 LBS. M = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-115

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

47830 LBS. FIXED PROPELLANT WEIGHT

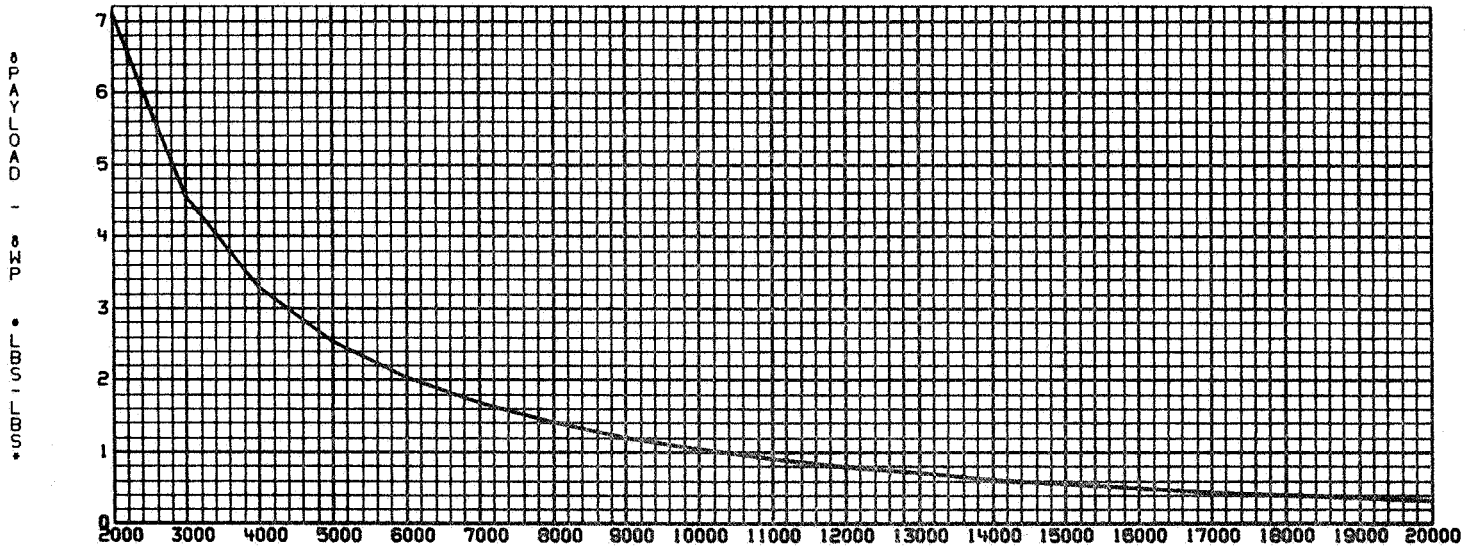


Figure 3-116

ALL FIXED IGNITION WEIGHTS

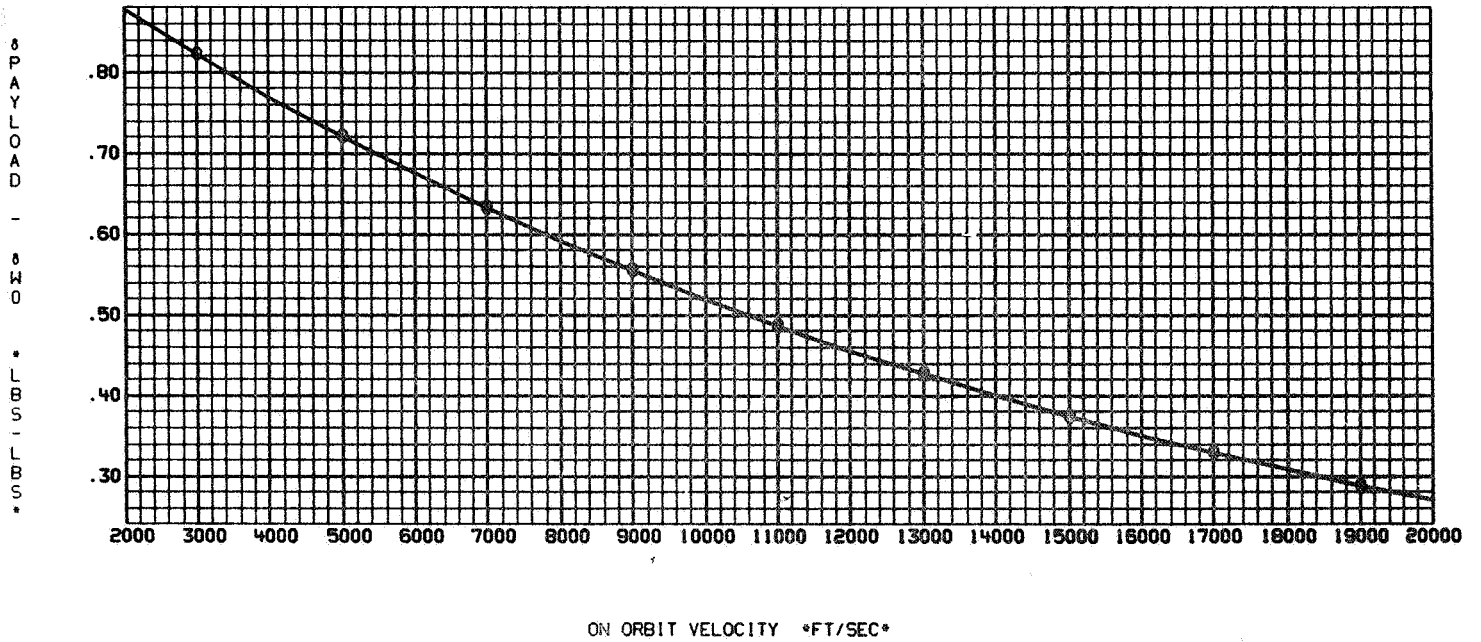


Figure 3-117

PAYLOAD DELIVERED	FIXED IGNITION WEIGHTS	EXPENDABLE TUG AND P/L
□ = FIXED IGNITION 15000 LBS.	○ = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
	X = FIXED IGNITION 45000 LBS.	

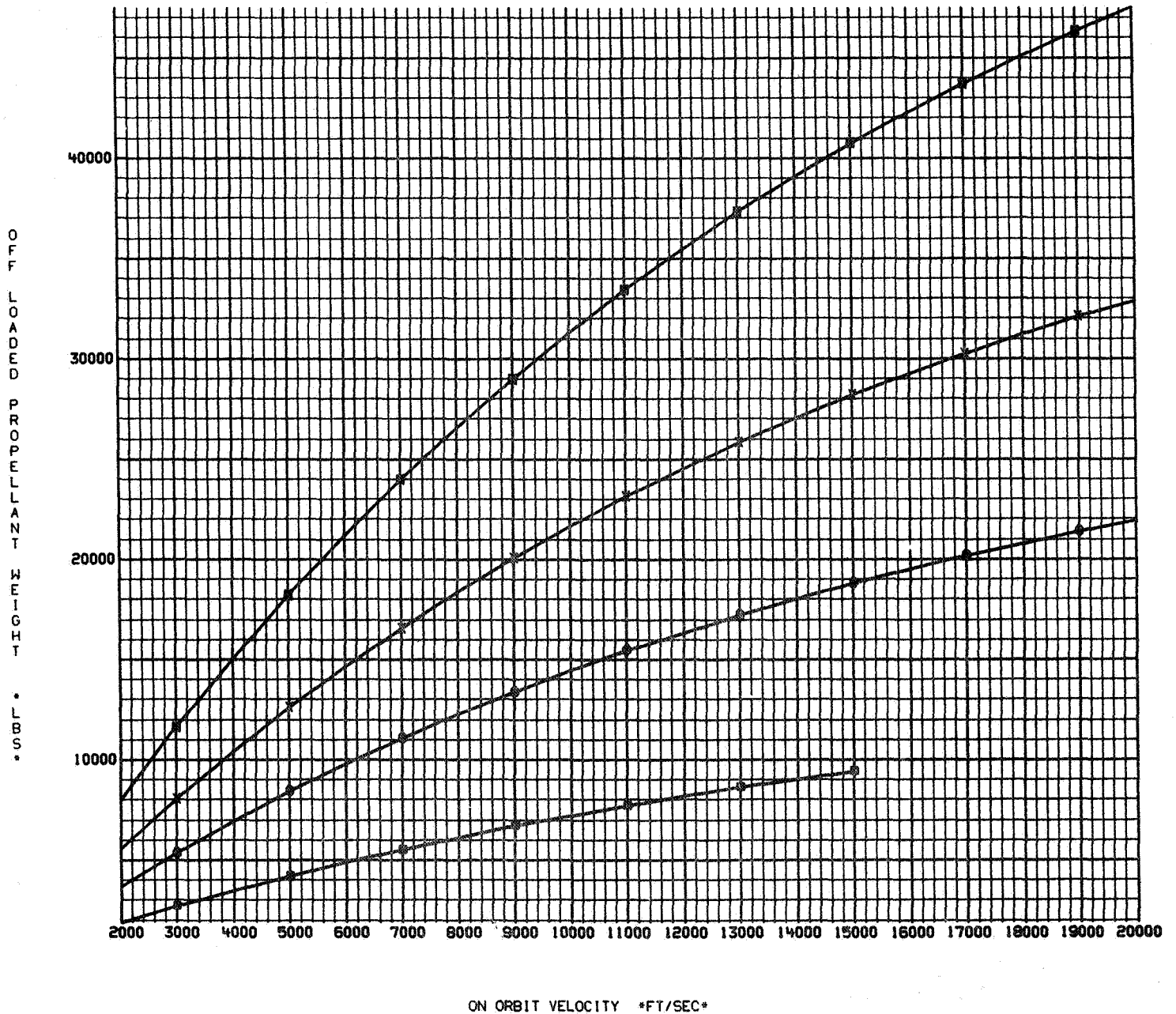


Figure 3-118

MODE 1

PAYLOAD RETURNED
 • = FIXED PROPELLANT 51994 LBS.
 □ = FIXED IGNITION 15000 LBS.

51994 LBS. FIXED PROPELLANT WEIGHT
 O = FIXED IGNITION 30000 LBS.
 X = FIXED IGNITION 45000 LBS.

ROUND TRIPPED P/L CAPABILITY
 ■ = FIXED IGNITION 65000 LBS.

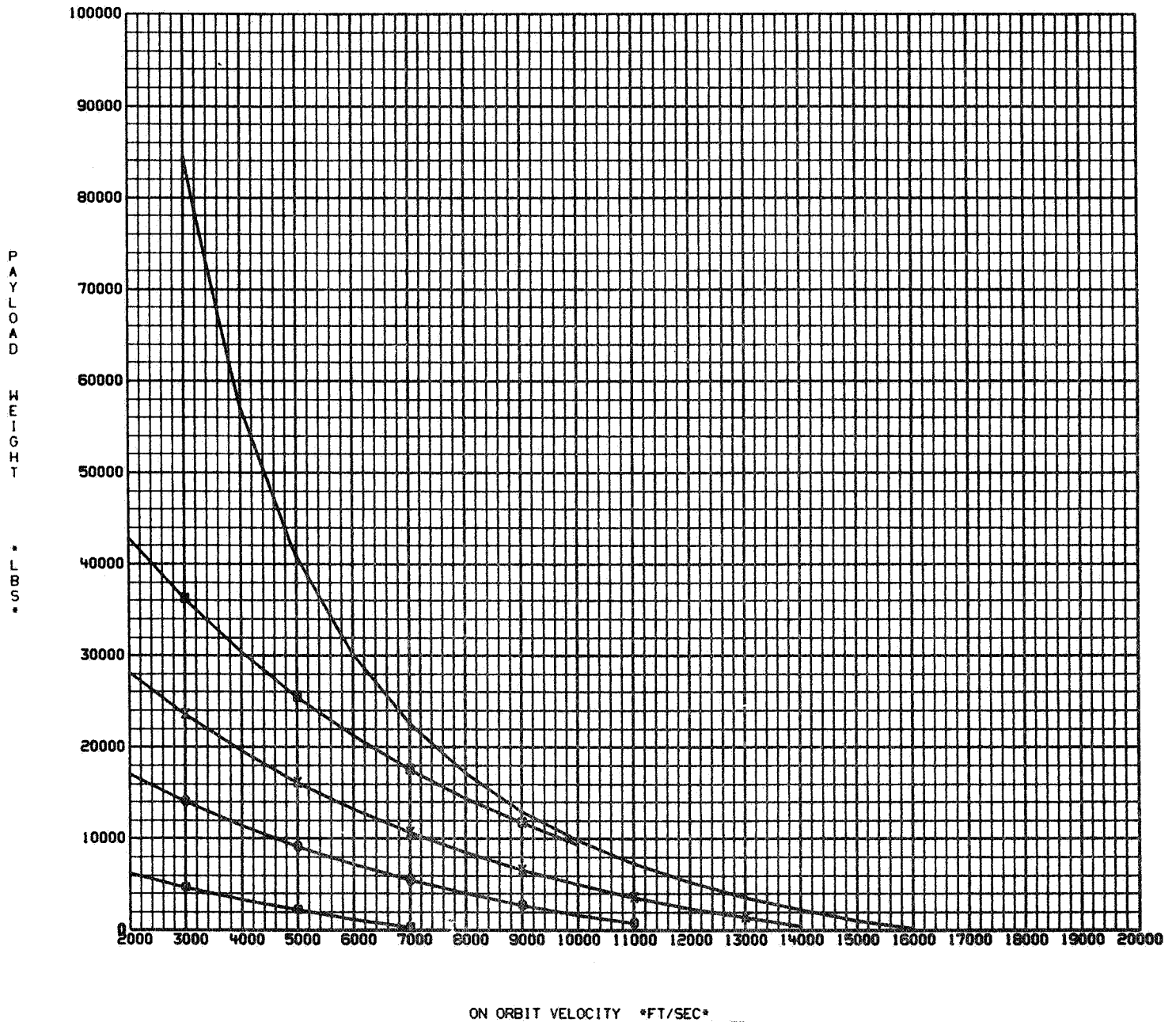


Figure 3-119

PAYLOAD RETURNED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT

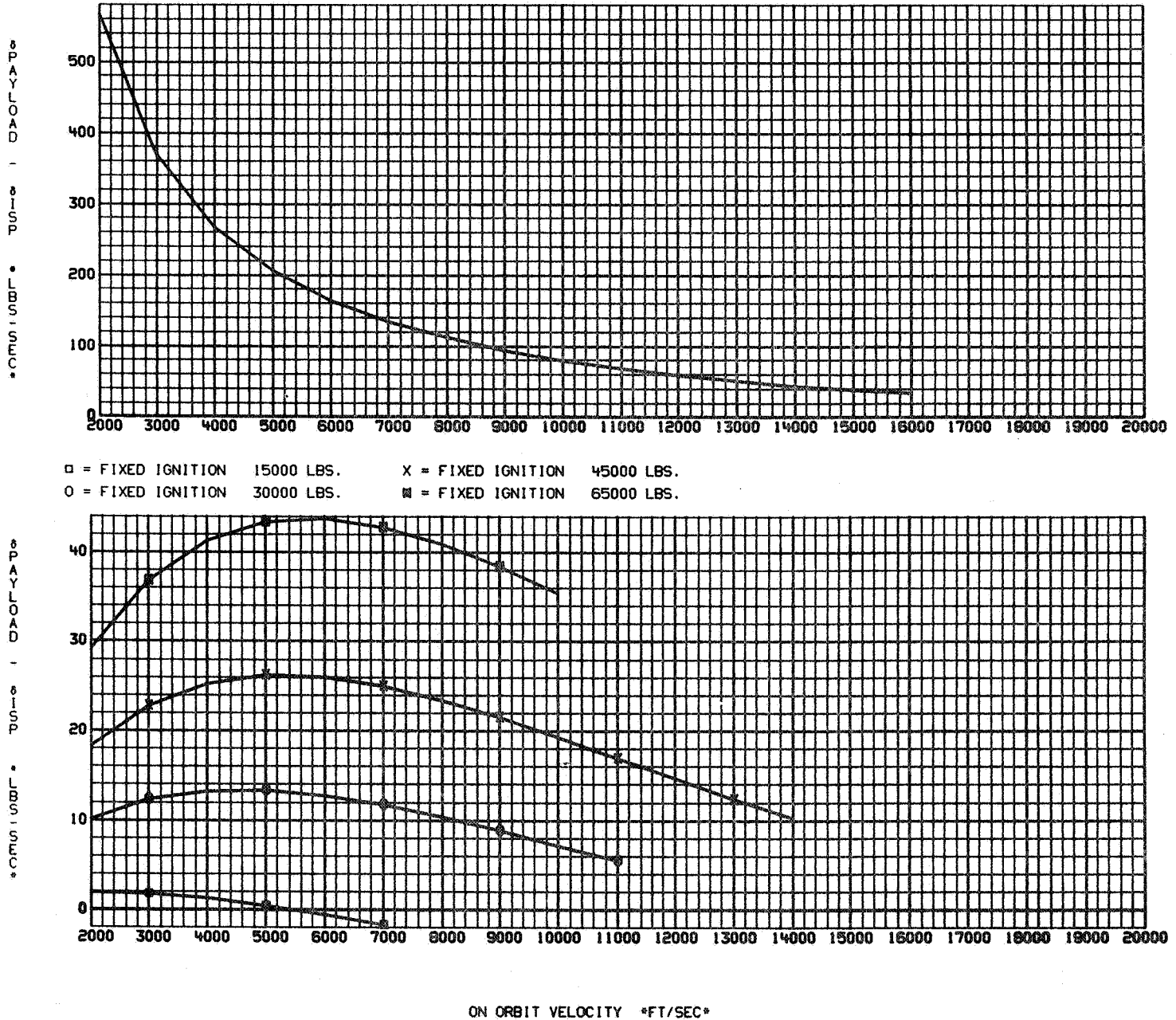
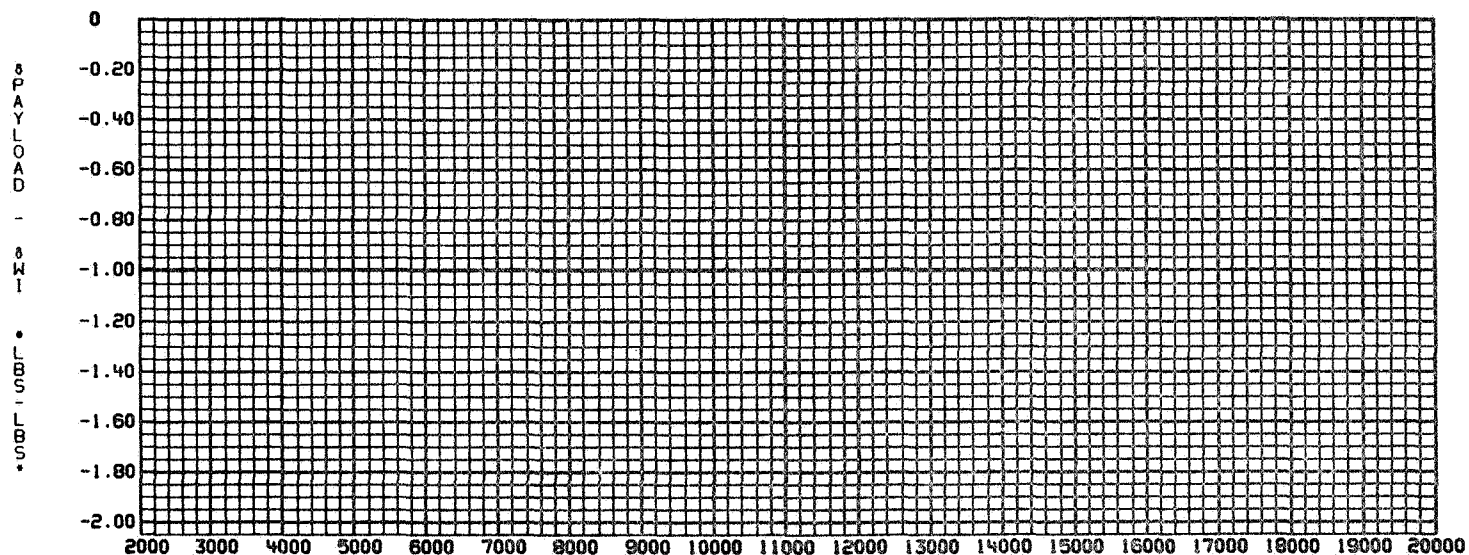


Figure 3-120

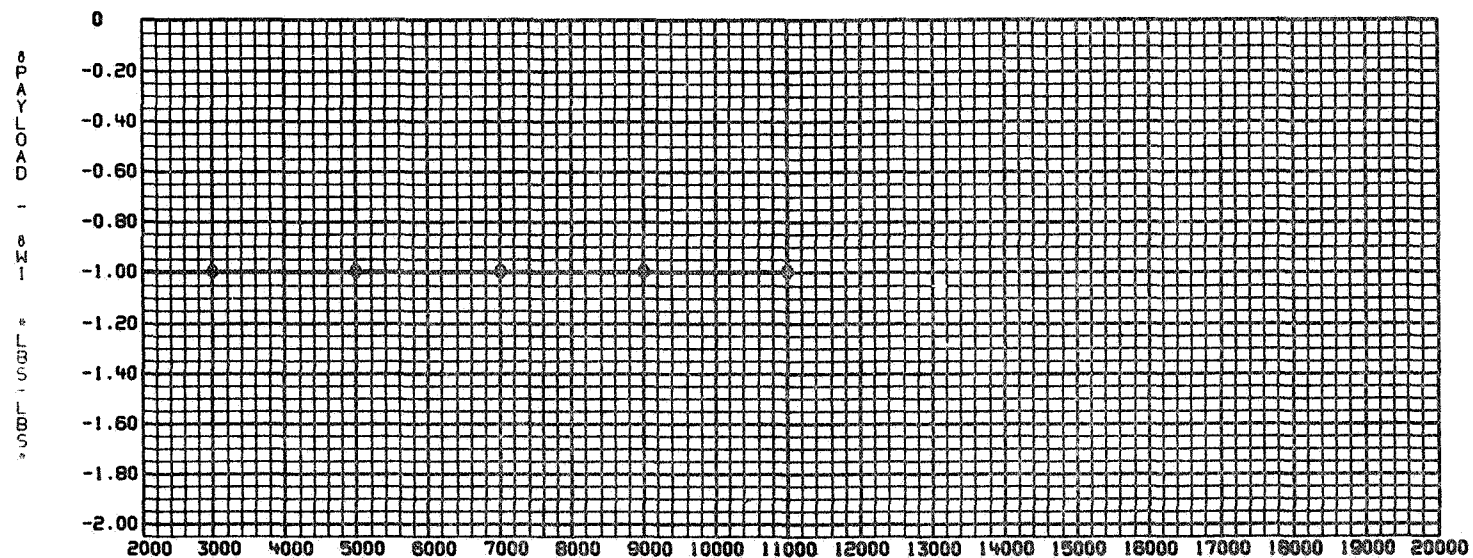
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



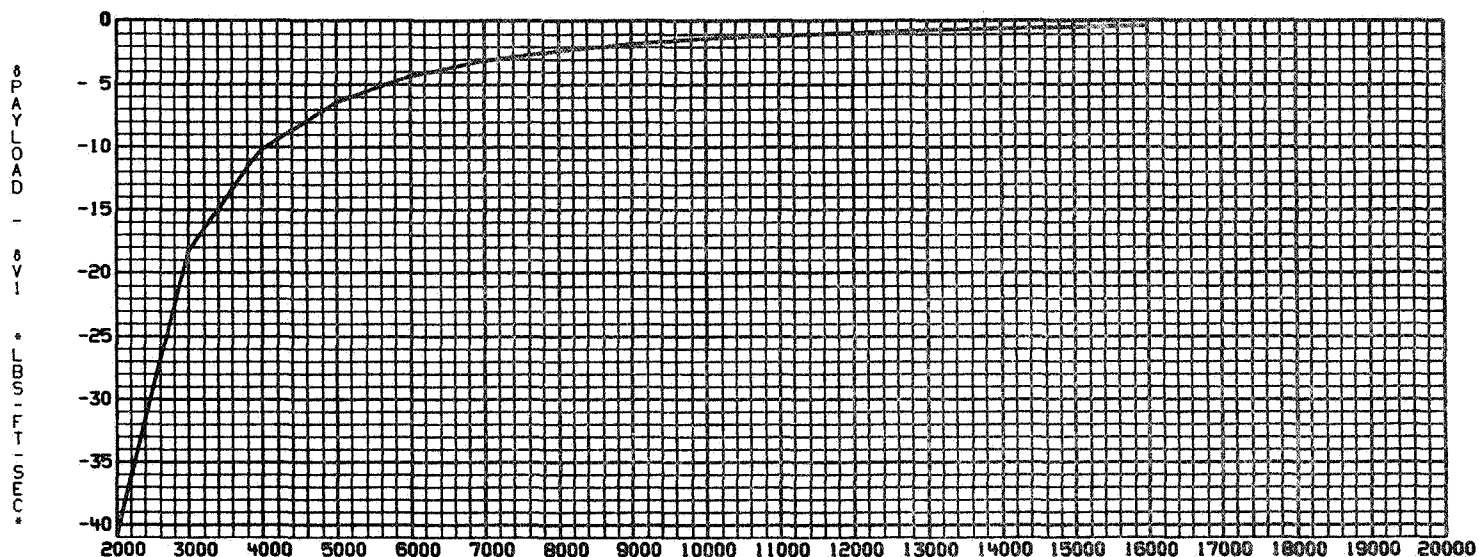
ON ORBIT VELOCITY *FT/SEC*

Figure 3-121

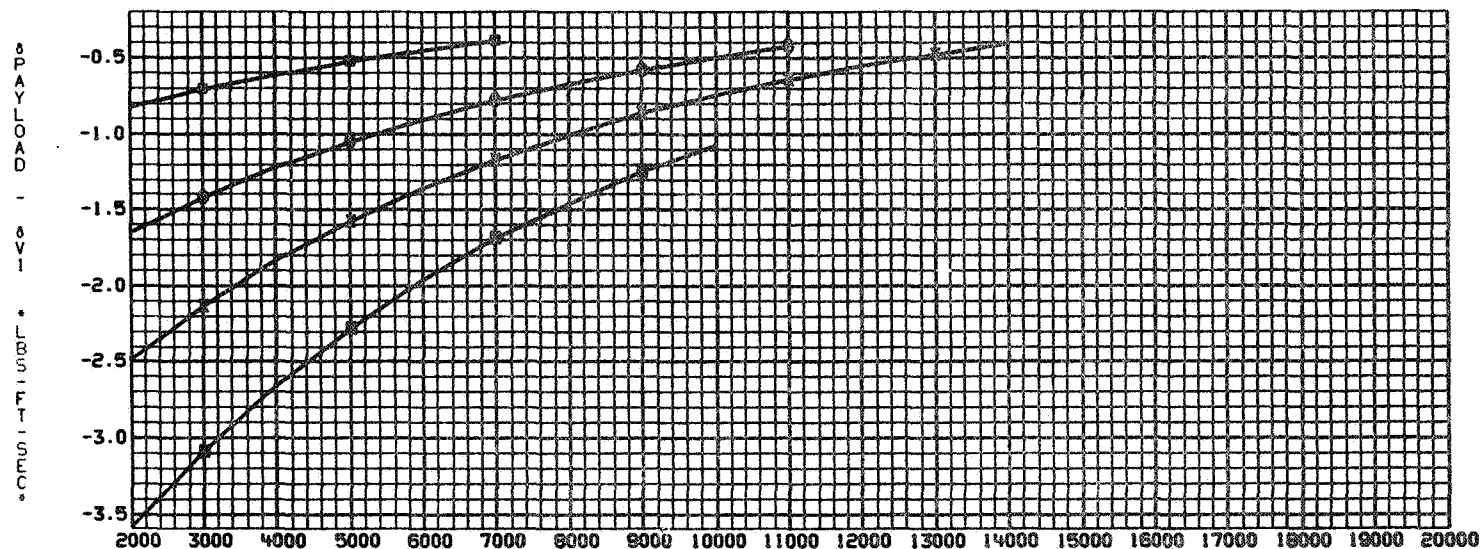
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



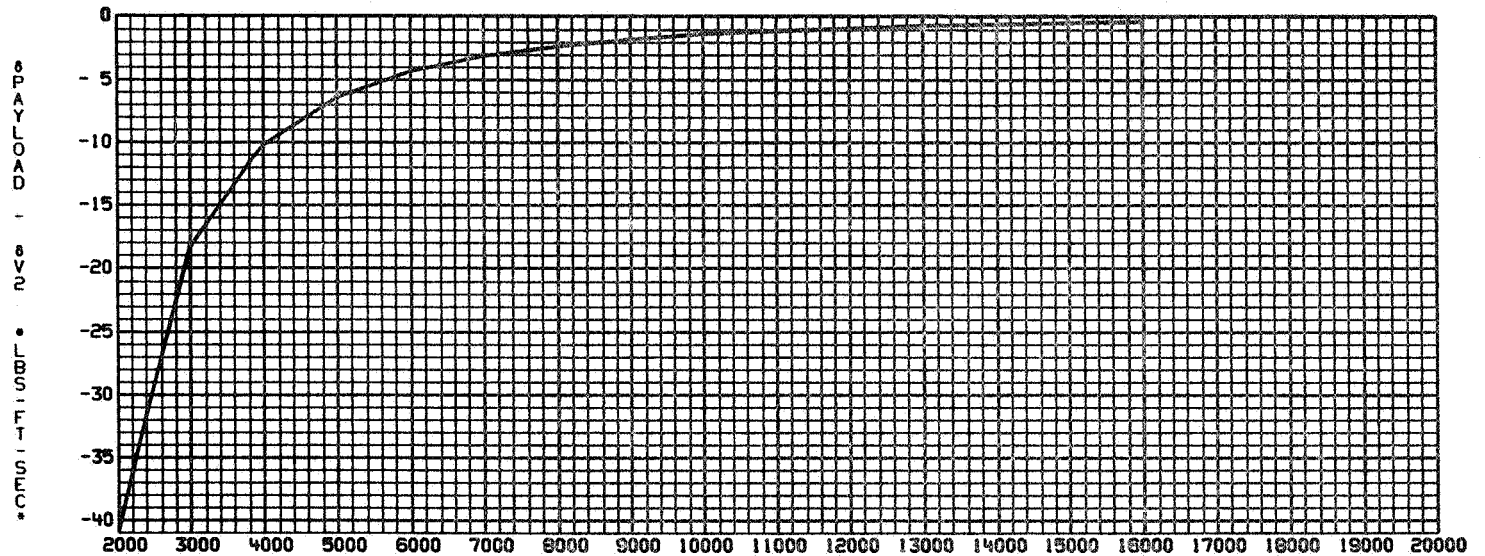
ON ORBIT VELOCITY *FT/SEC*

Figure 3-122

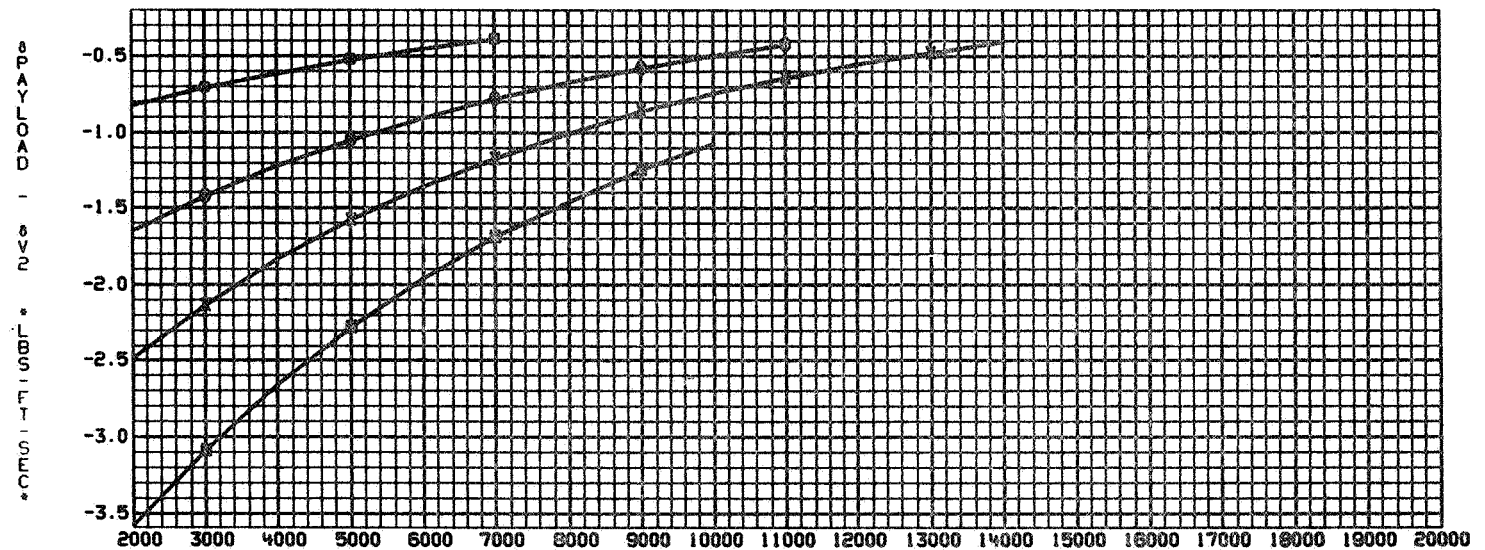
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-123

PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT

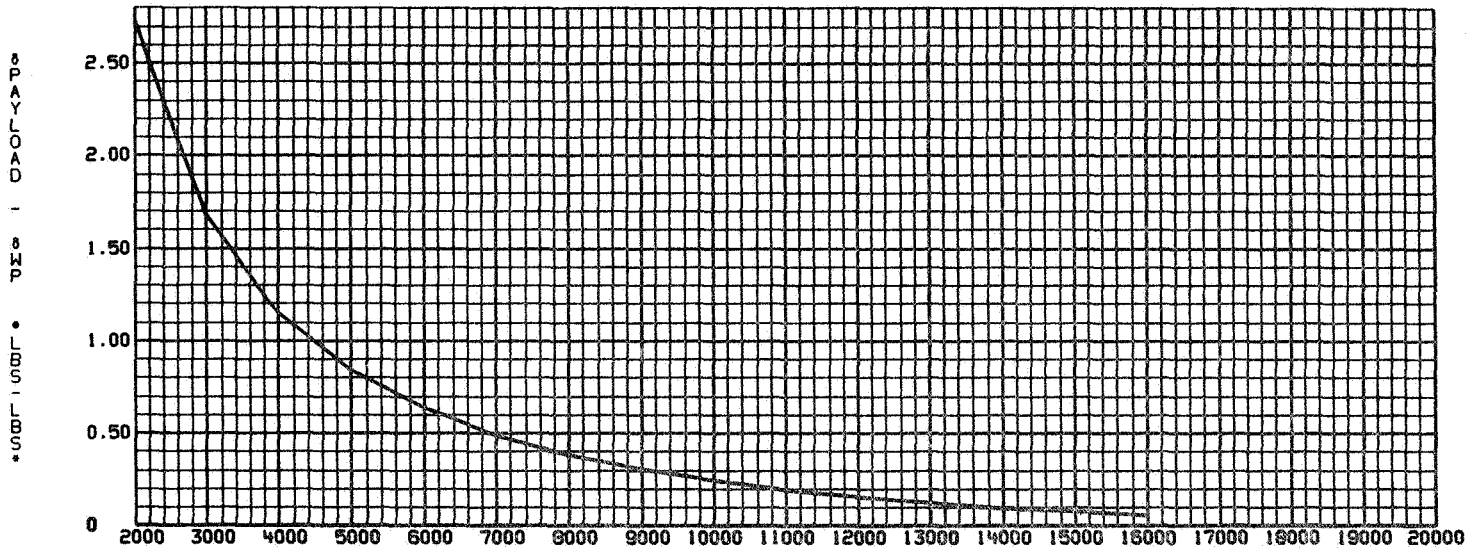


Figure 3-124

ALL FIXED IGNITION WEIGHTS

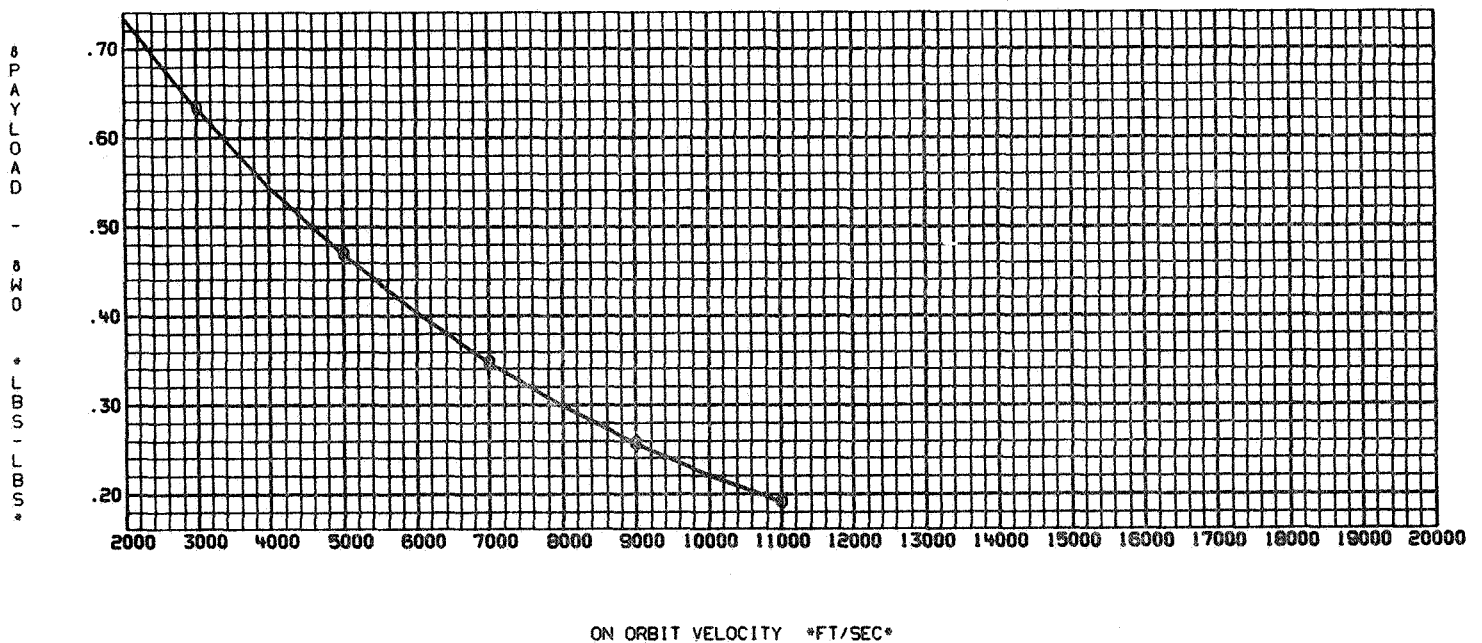
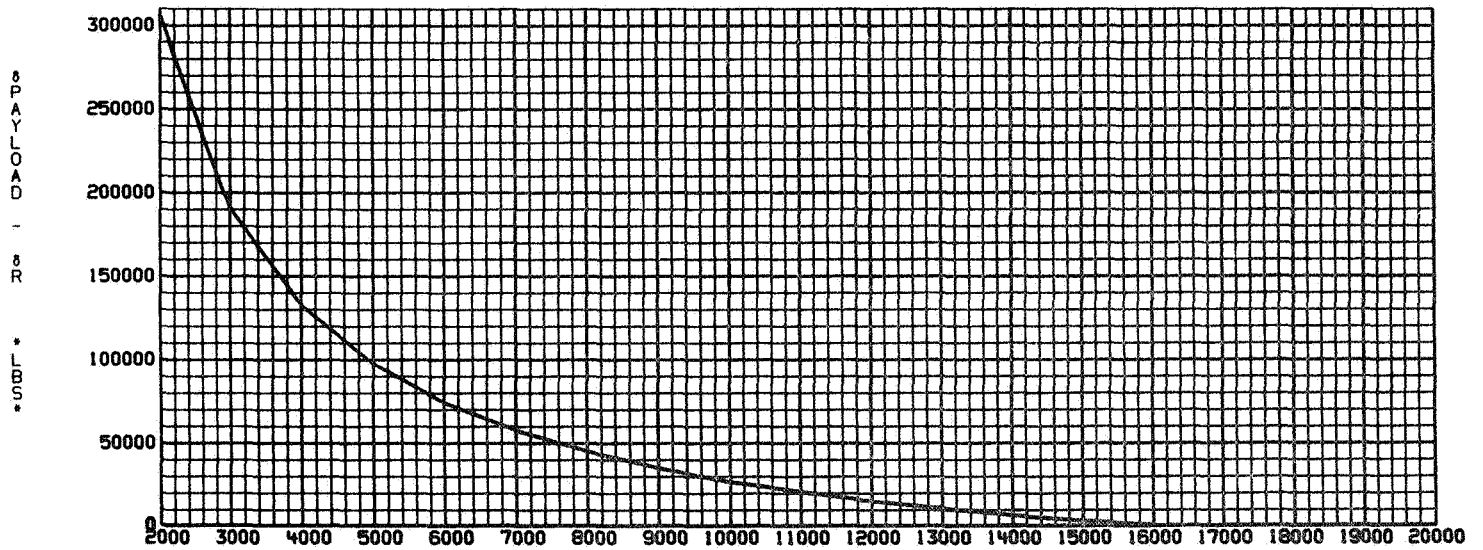


Figure 3-125

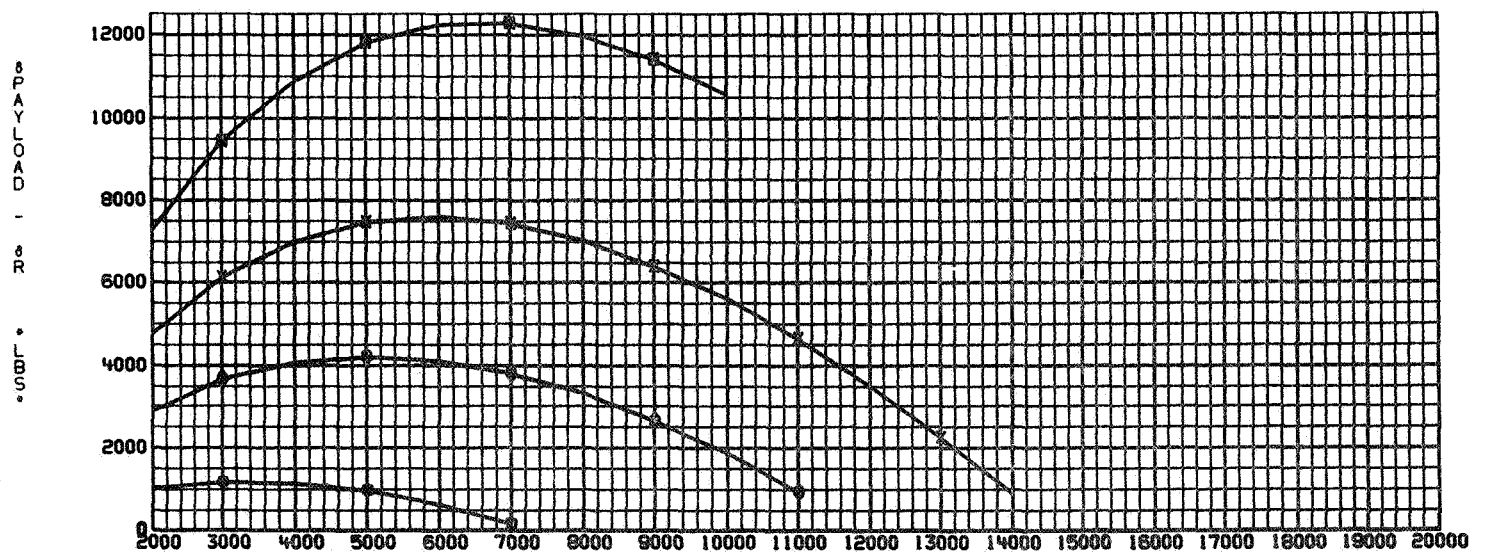
PAYLOAD DELIVERED

ROUND TRIPPED P/L CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-126

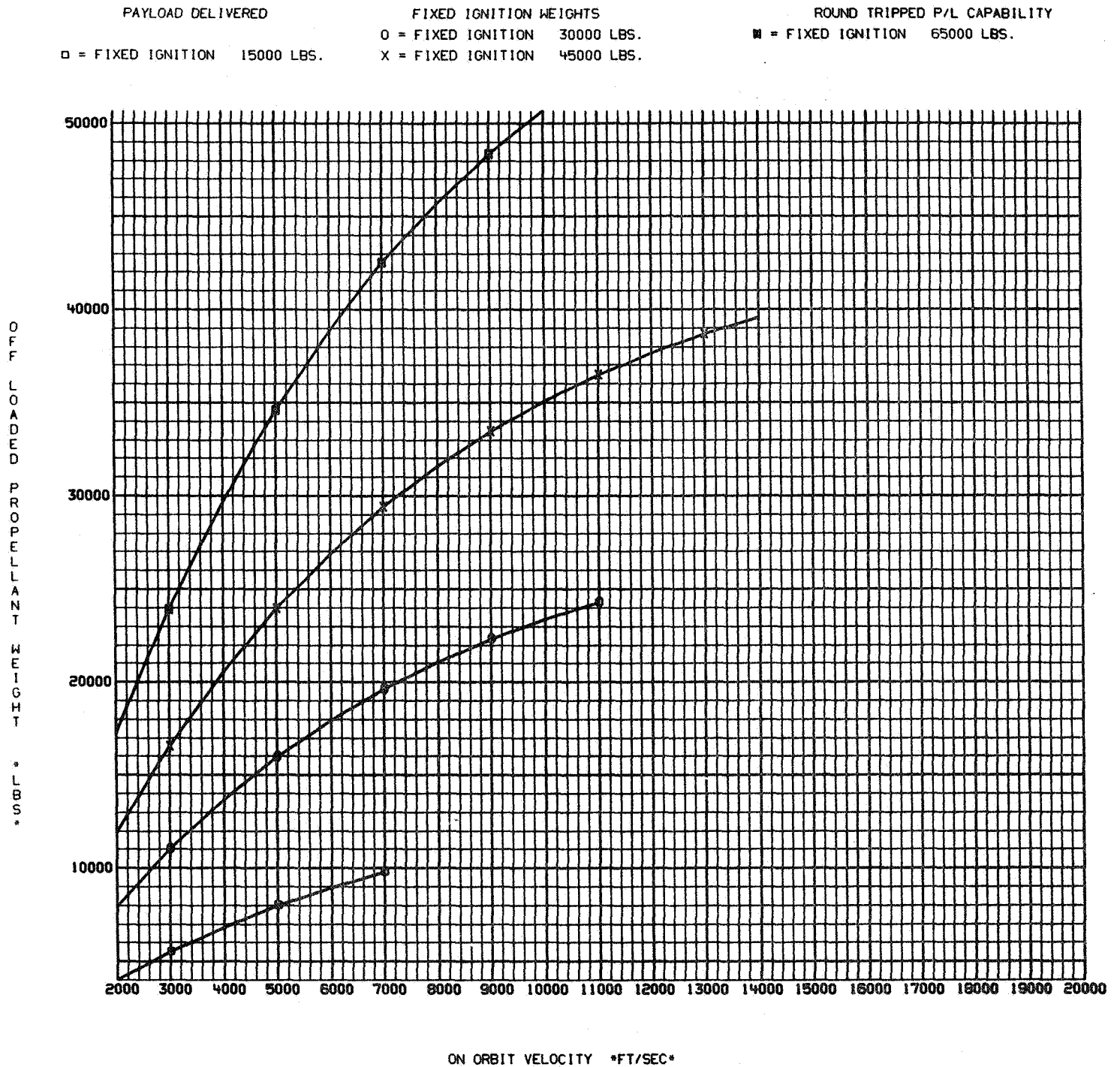


Figure 3-127

MODE 2

PAYLOAD RETURNED		51994 LBS. FIXED PROPELLANT WEIGHT		TUG - P/L RETRIEVAL CAPABILITY
• = FIXED PROPELLANT 51994 LBS.		O = FIXED IGNITION 30000 LBS.		■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.		X = FIXED IGNITION 45000 LBS.		

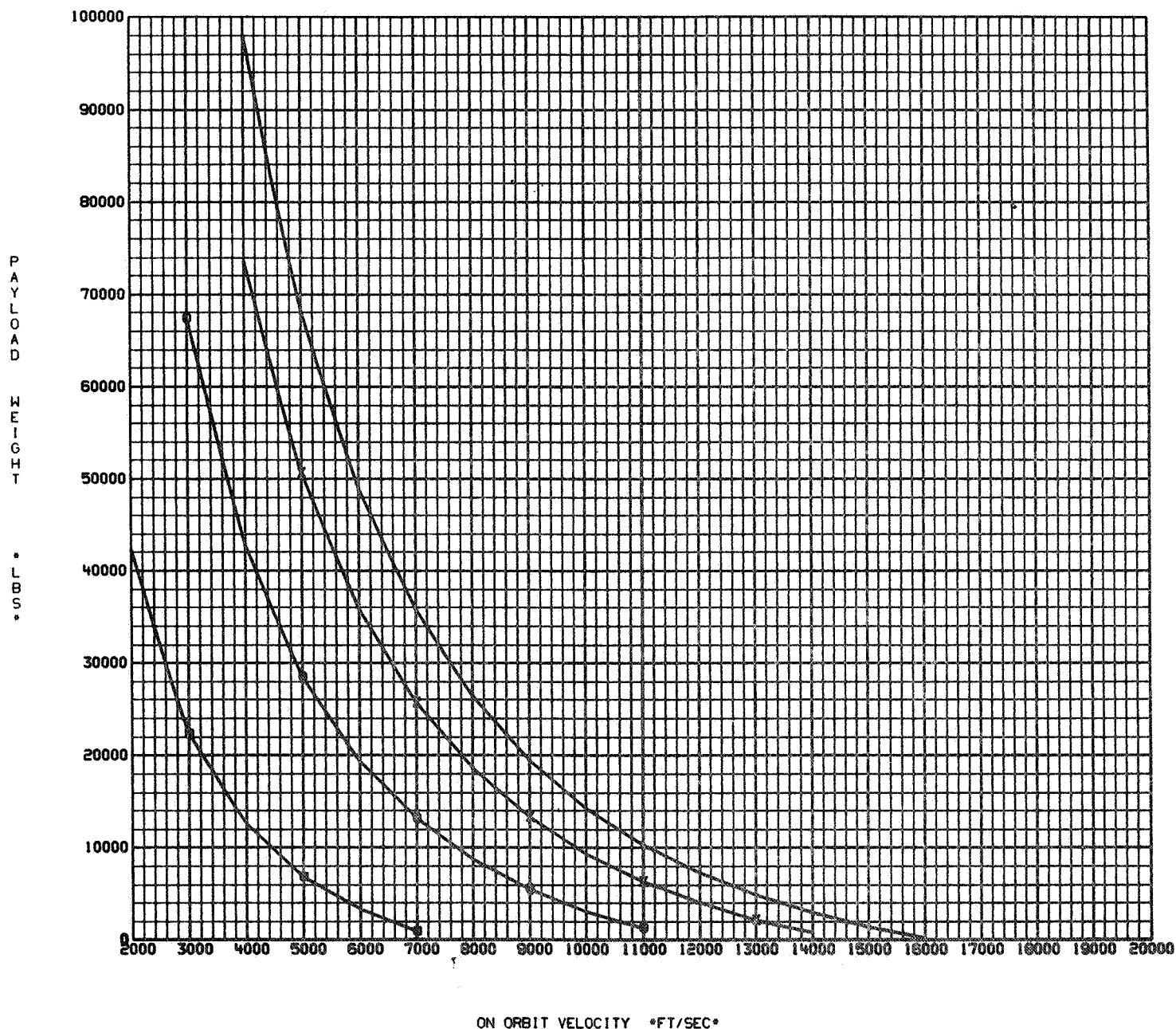
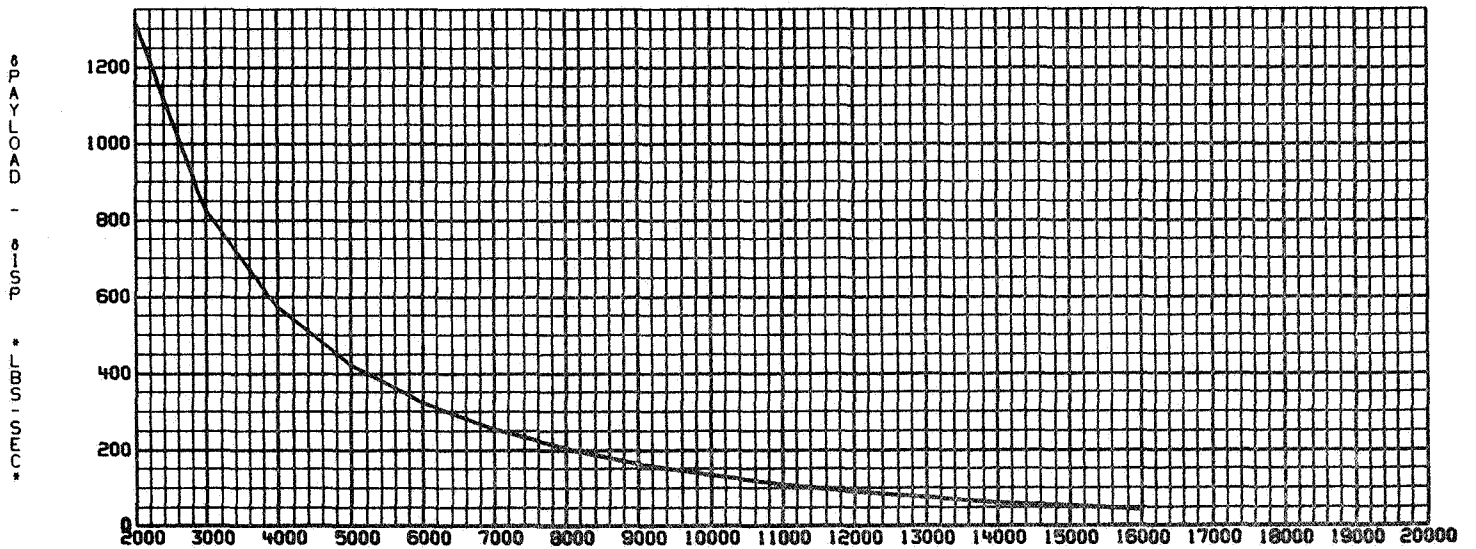


Figure 3-128

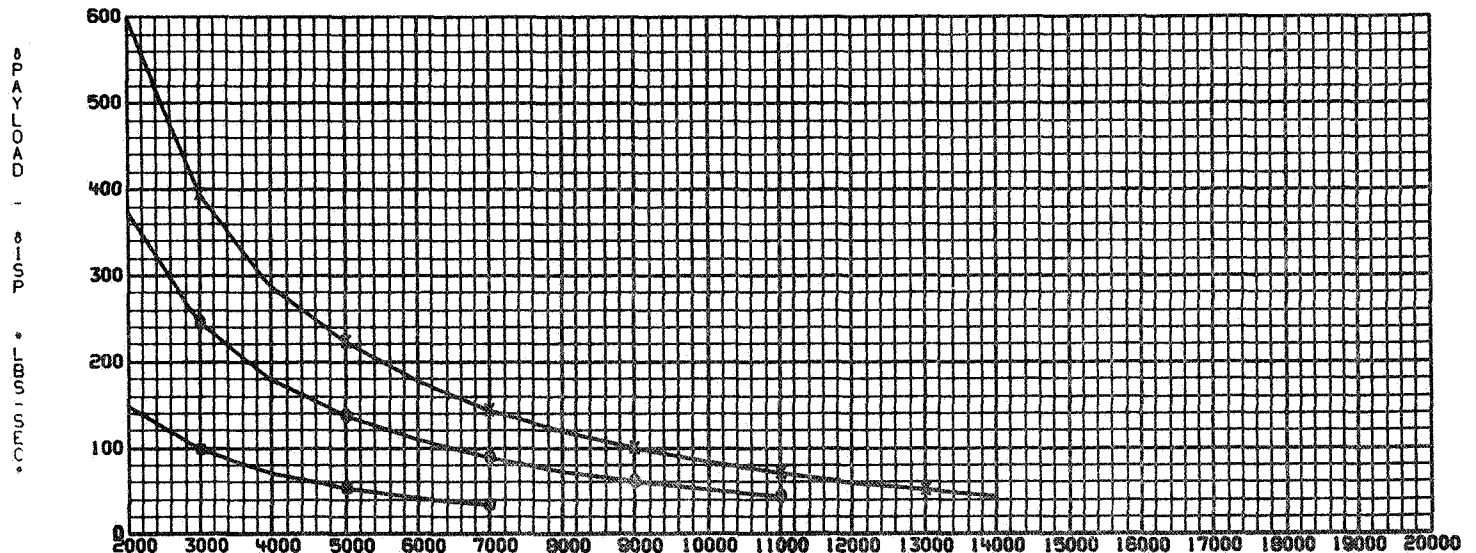
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



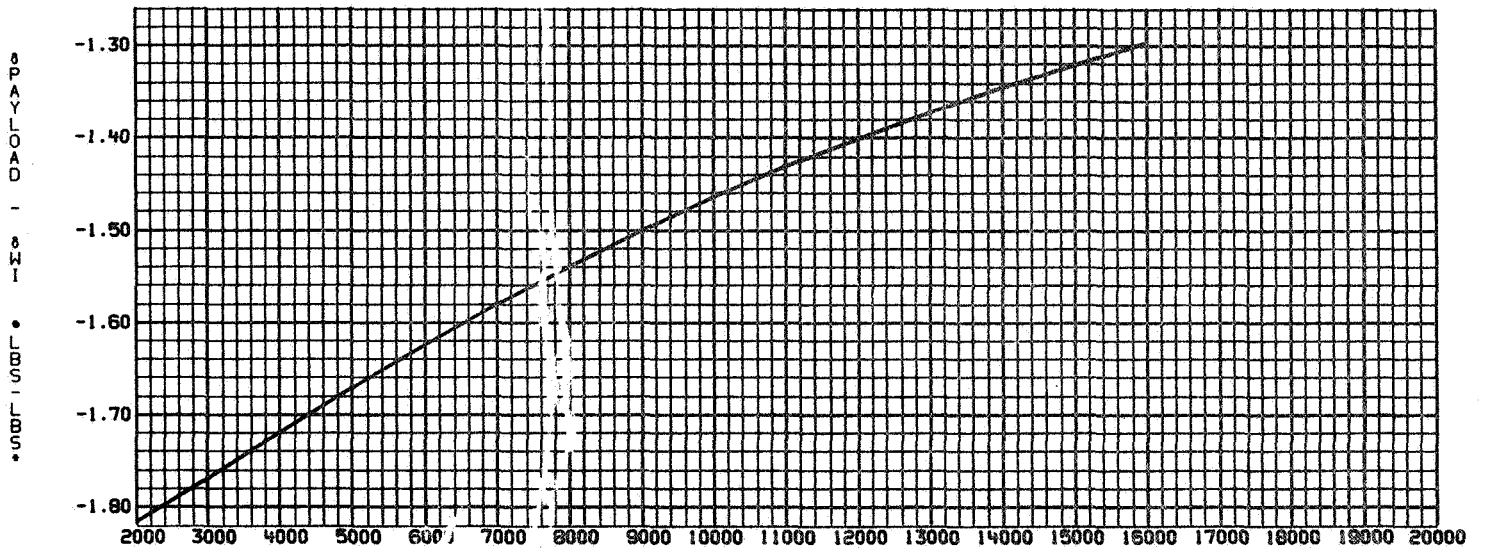
ON ORBIT VELOCITY *FT/SEC*

Figure 3-129

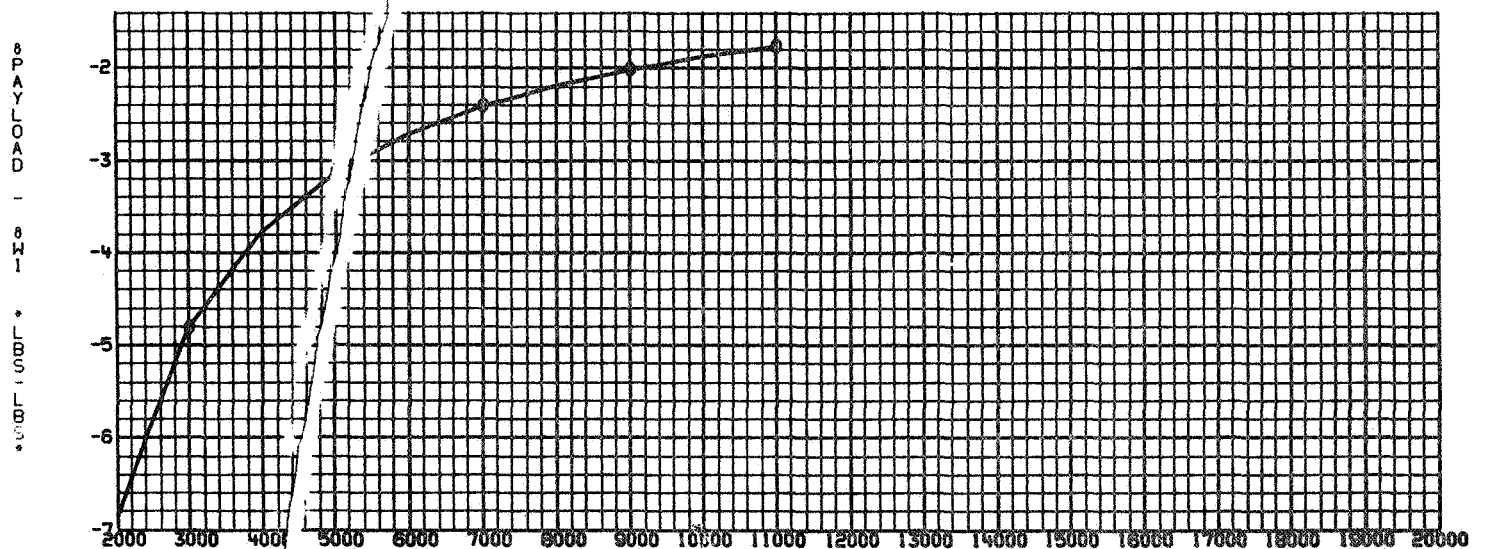
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



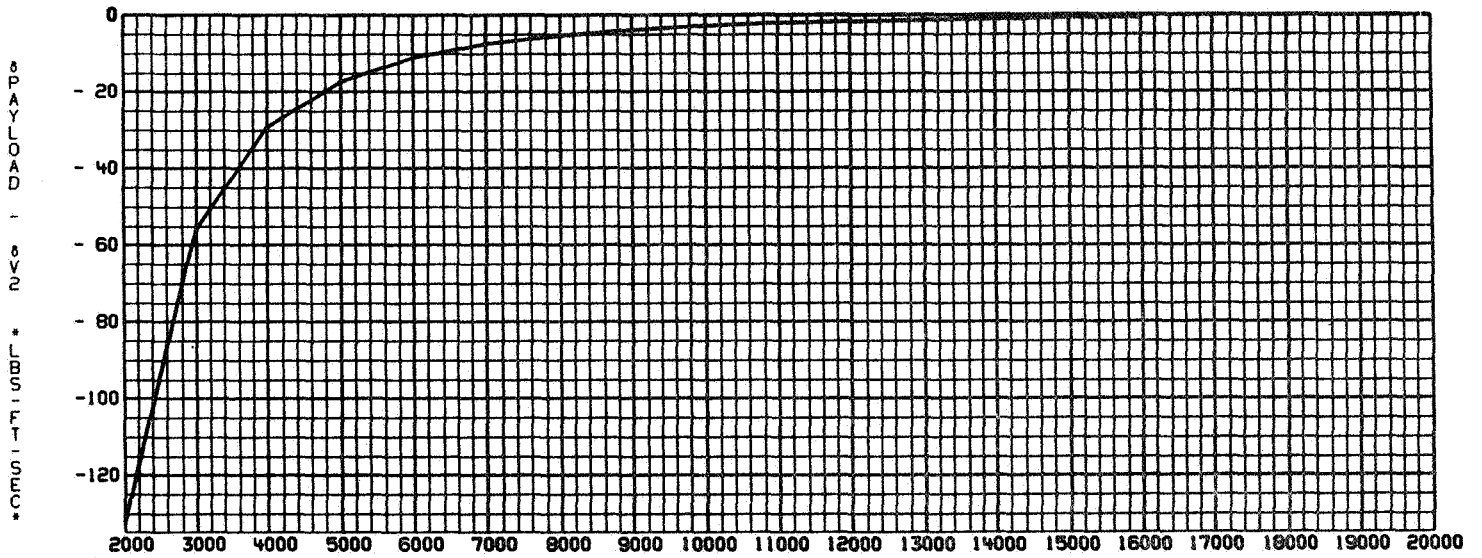
ON ORBIT VELOCITY *FT/SEC*

Figure 3-130

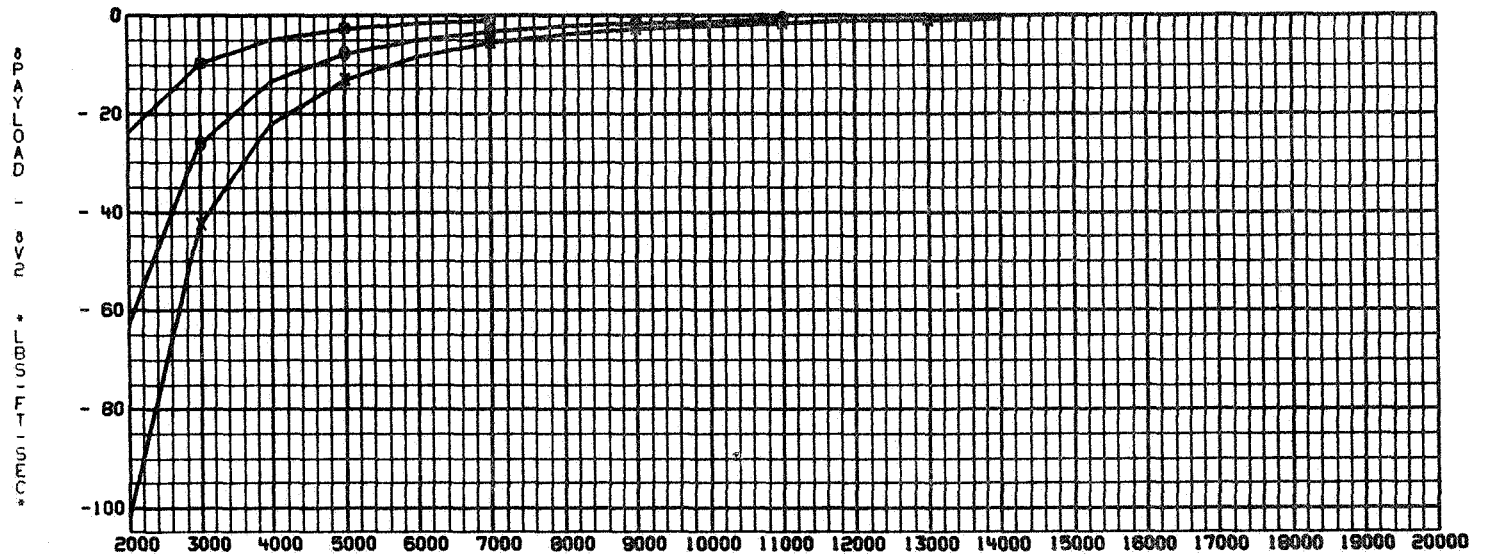
PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-131

PAYLOAD RETURNED

TUG - P/L RETRIEVAL CAPABILITY

51994 LBS. FIXED PROPELLANT WEIGHT

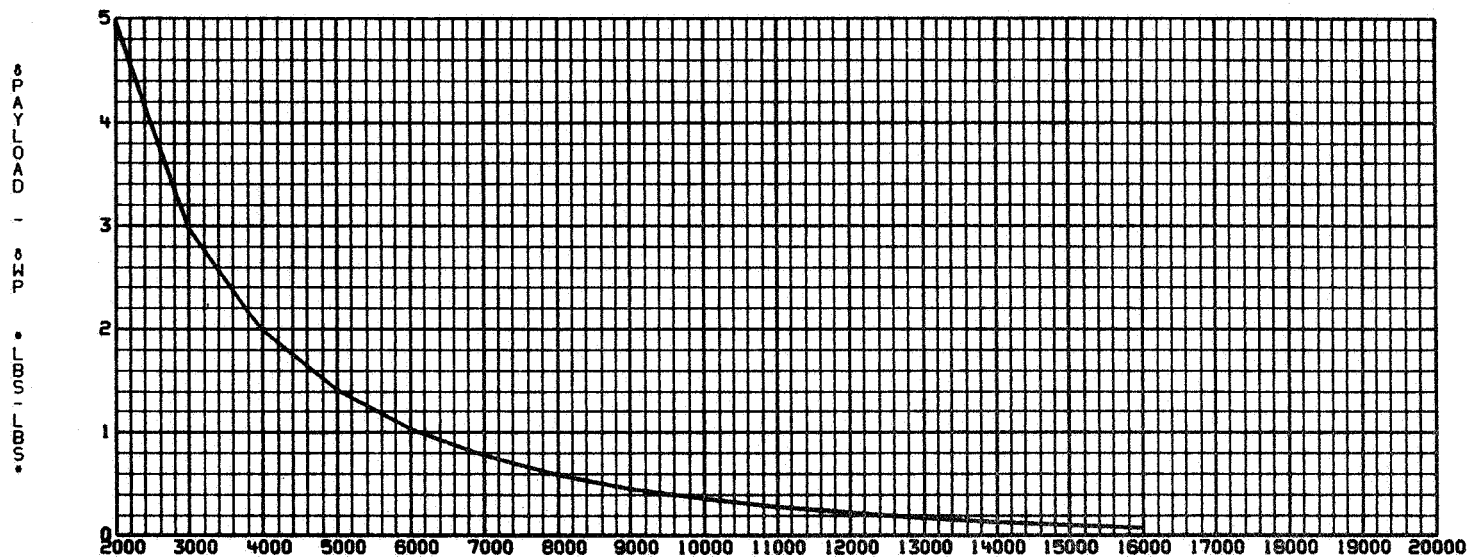


Figure 3-132

ALL FIXED IGNITION WEIGHTS

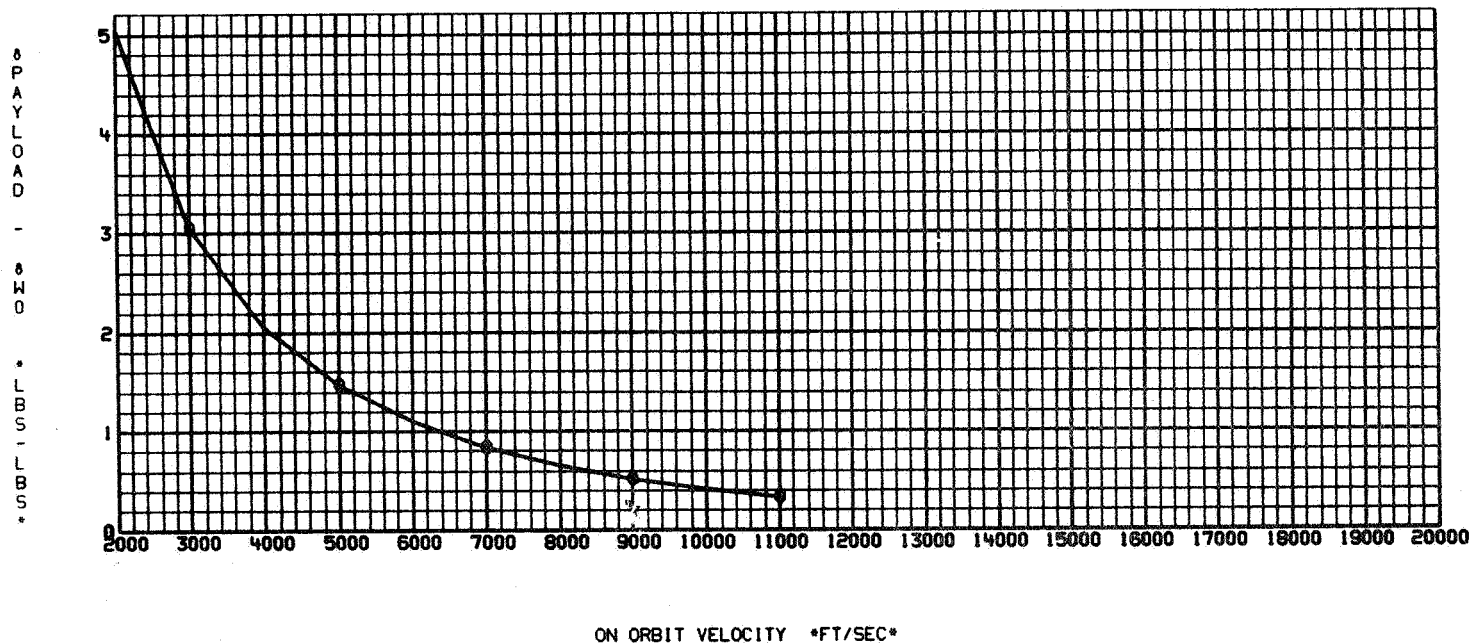


Figure 3-133

NOTE

Offloaded propellant
in Mode 2 is not
a function of ΔV

Figure 3-134

3-118

MODE 3

PAYLOAD DELIVERED
 . = FIXED PROPELLANT 51994 LBS.
 □ = FIXED IGNITION 15000 LBS.

51994 LBS. FIXED PROPELLANT WEIGHT
 O = FIXED IGNITION 30000 LBS.
 X = FIXED IGNITION 45000 LBS.

EXPENDABLE P/L ** REUSEABLE TUG
 ■ = FIXED IGNITION 65000 LBS.

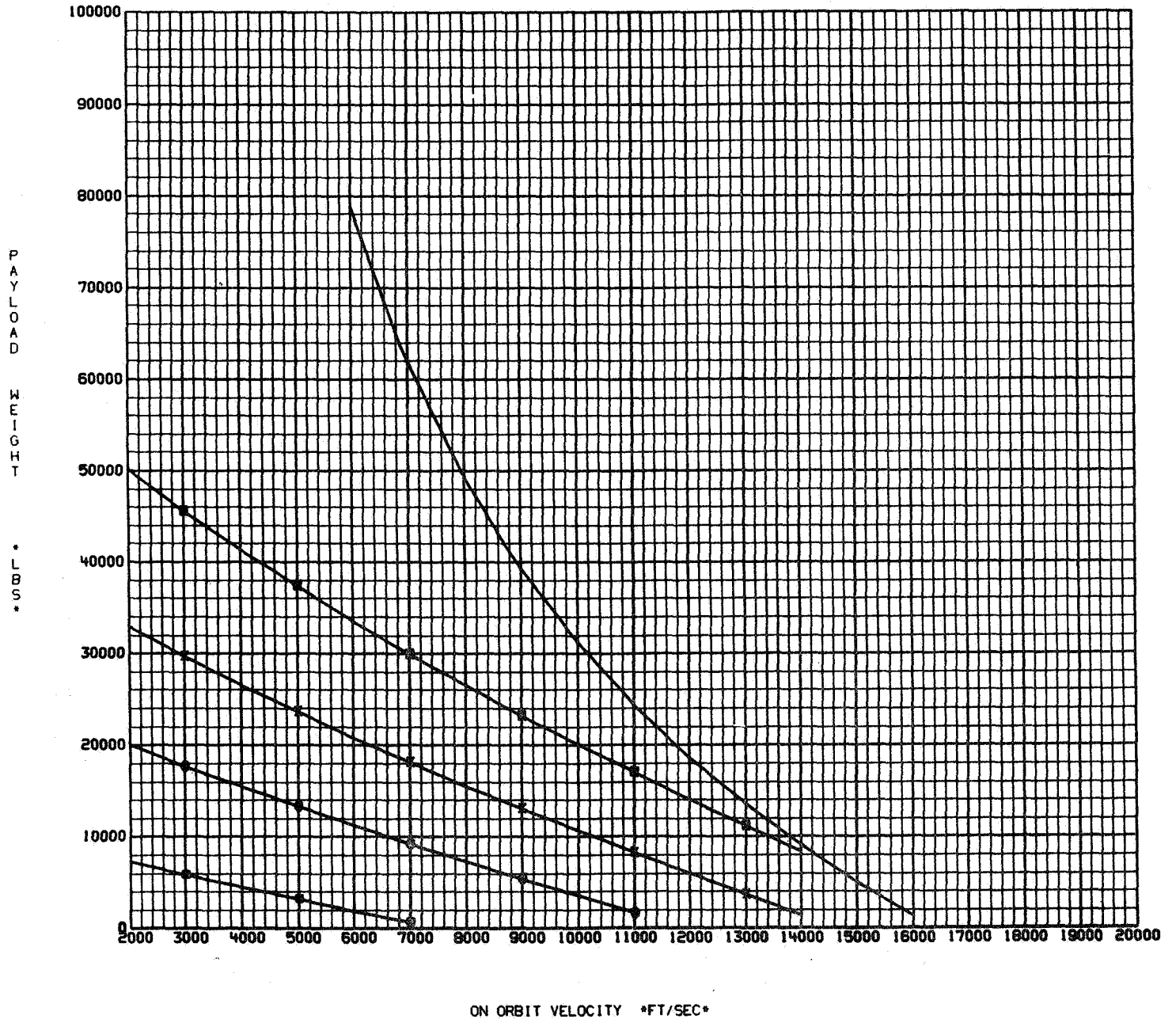
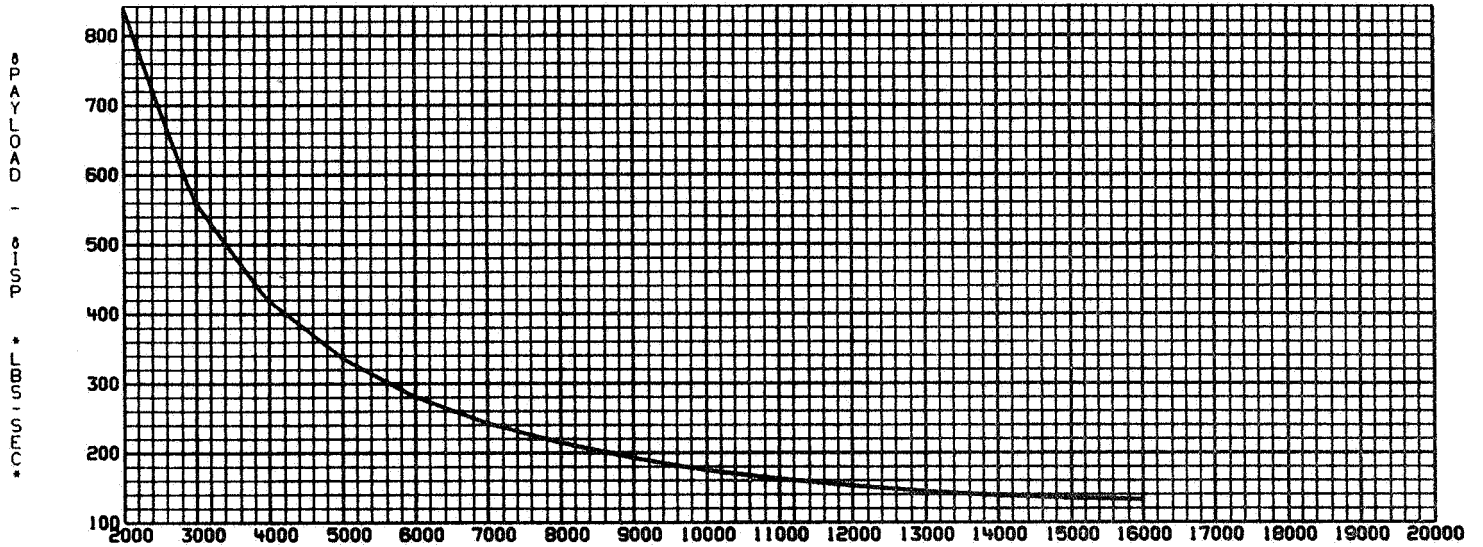


Figure 3-135

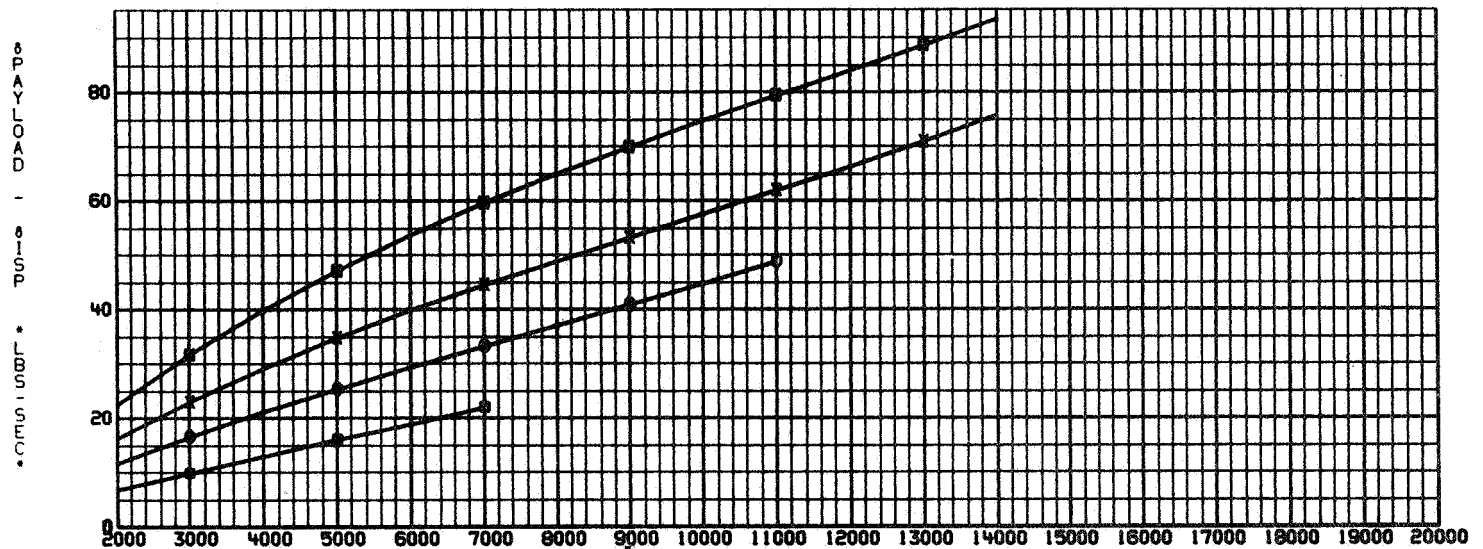
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
○ = FIXED IGNITION 30000 LBS. ■ = FIXED IGNITION 65000 LBS.



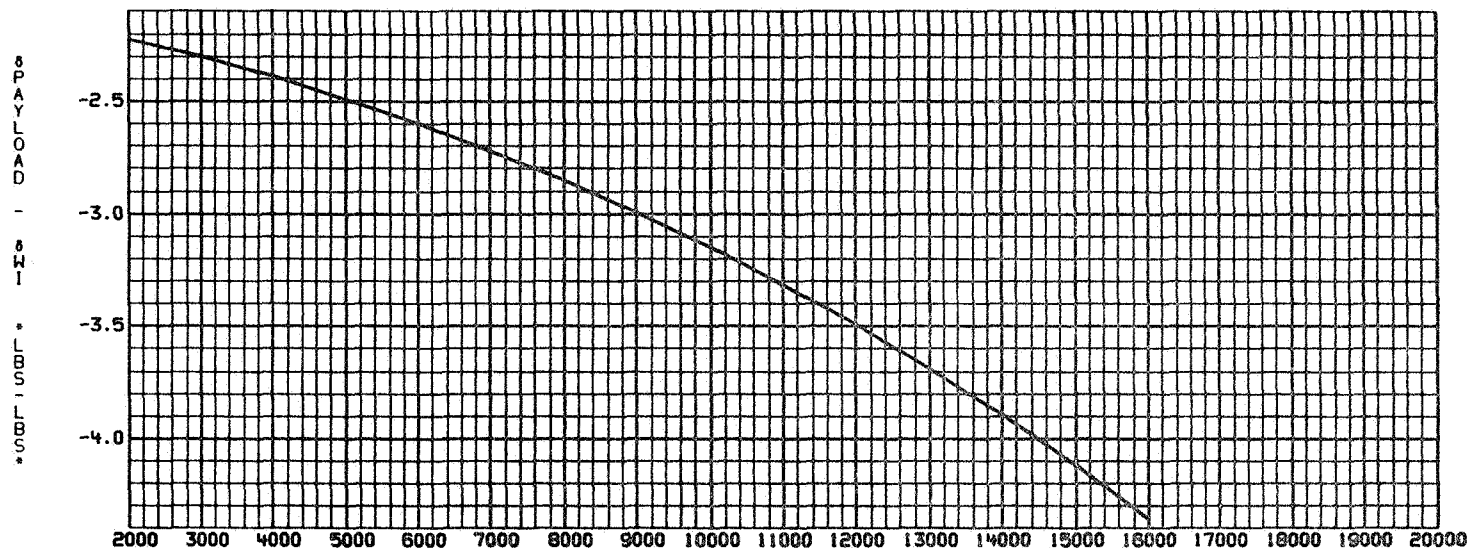
ON ORBIT VELOCITY *FT/SEC*

Figure 3-136

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS

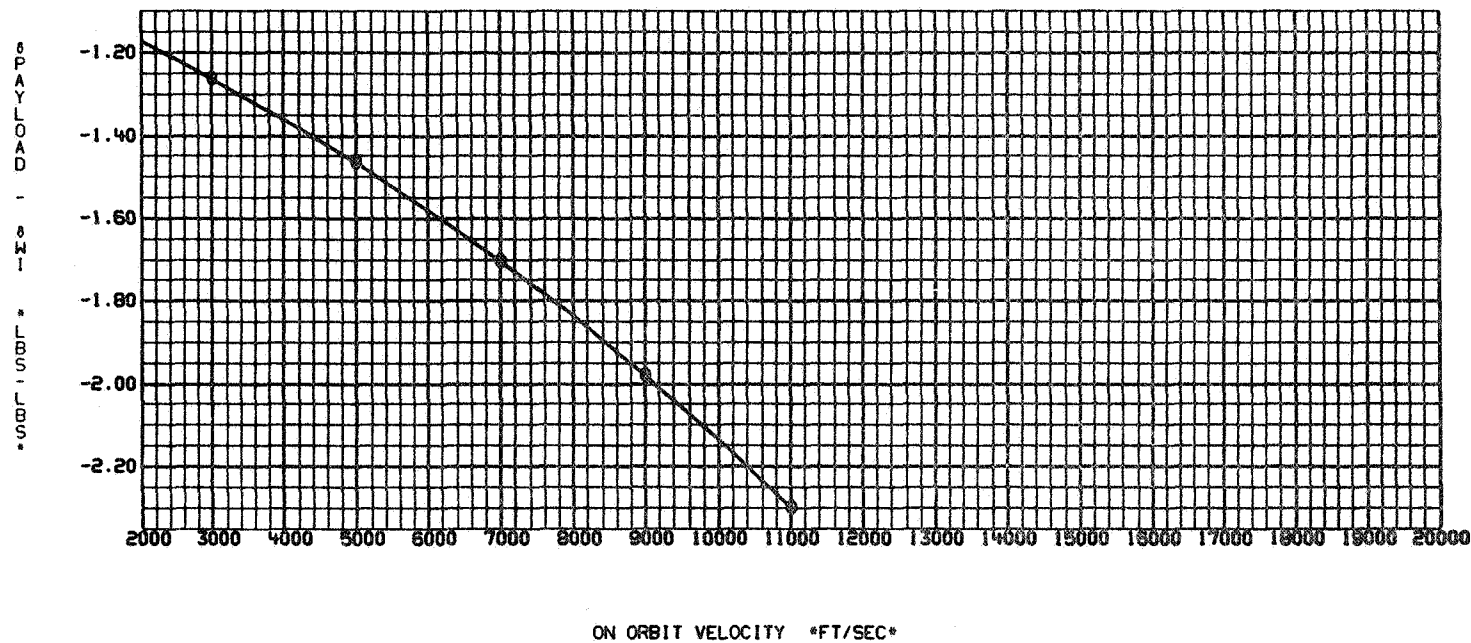
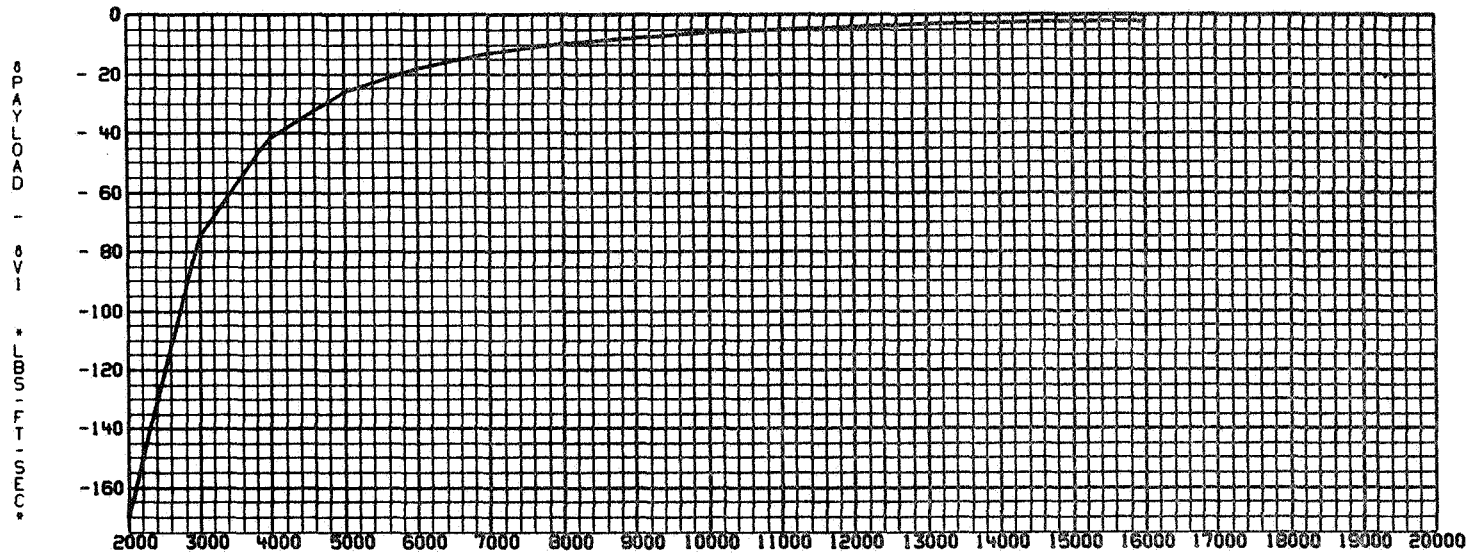


Figure 3-137

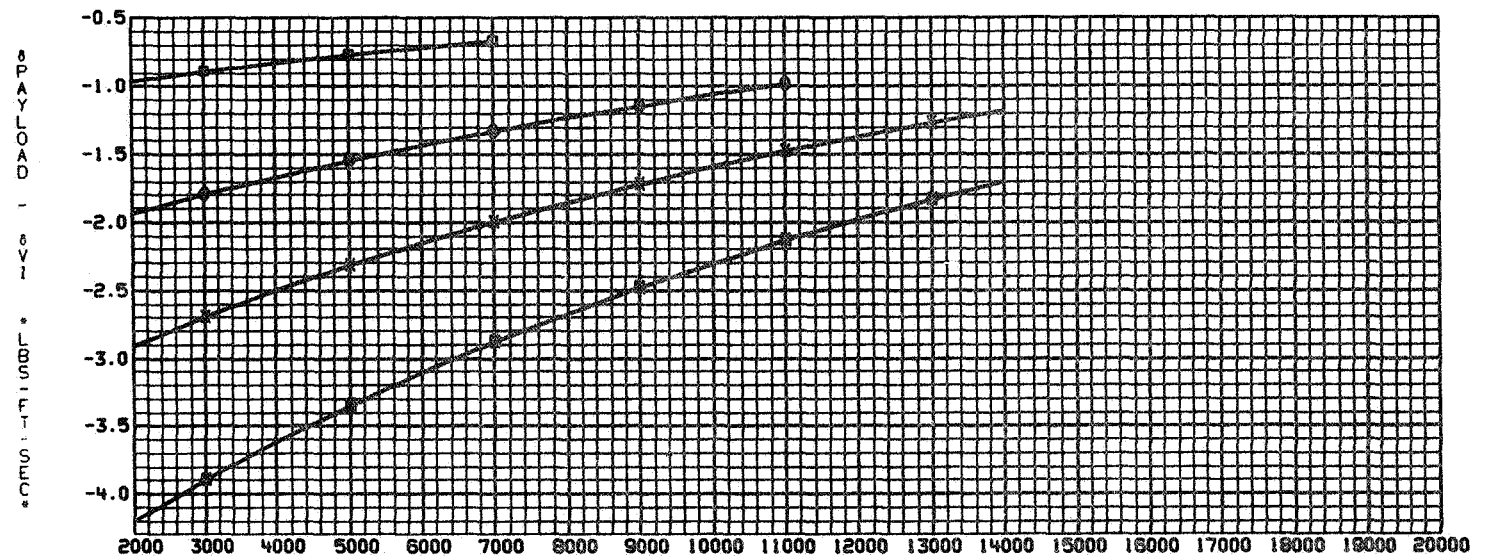
PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT



■ = FIXED IGNITION 15000 LBS. X = FIXED IGNITION 45000 LBS.
 ○ = FIXED IGNITION 30000 LBS. □ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-138

PAYLOAD DELIVERED

EXPENDABLE P/L ** REUSEABLE TUG

51994 LBS. FIXED PROPELLANT WEIGHT

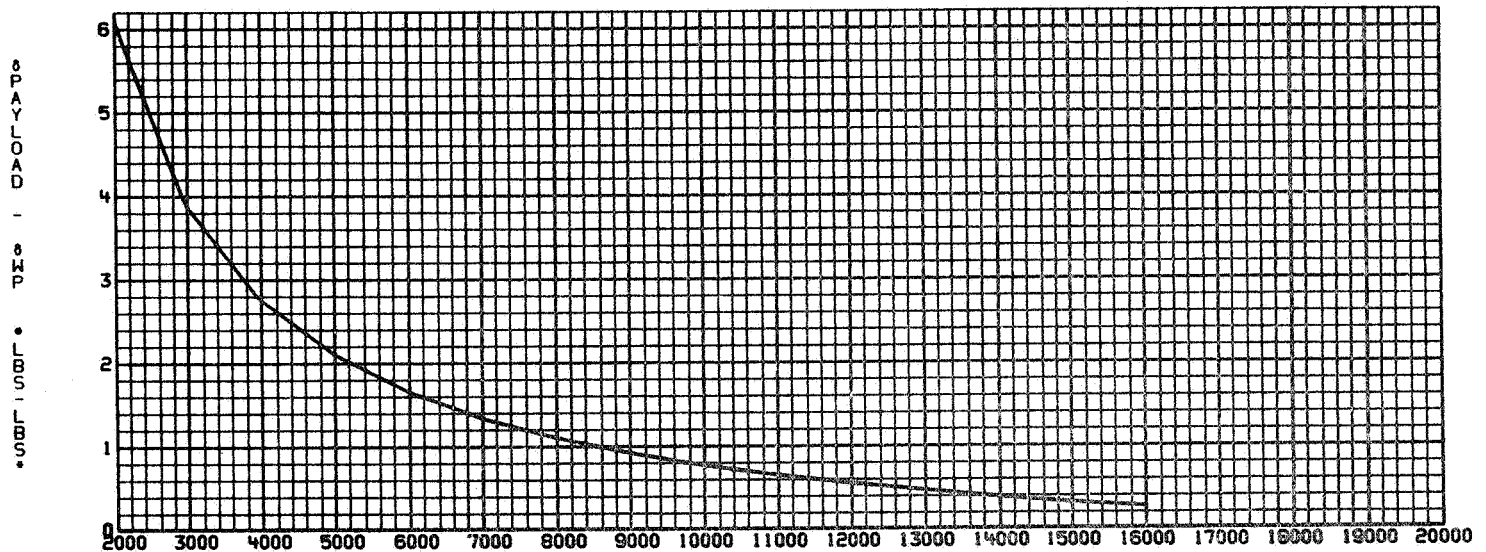


Figure 3-139

ALL FIXED IGNITION WEIGHTS

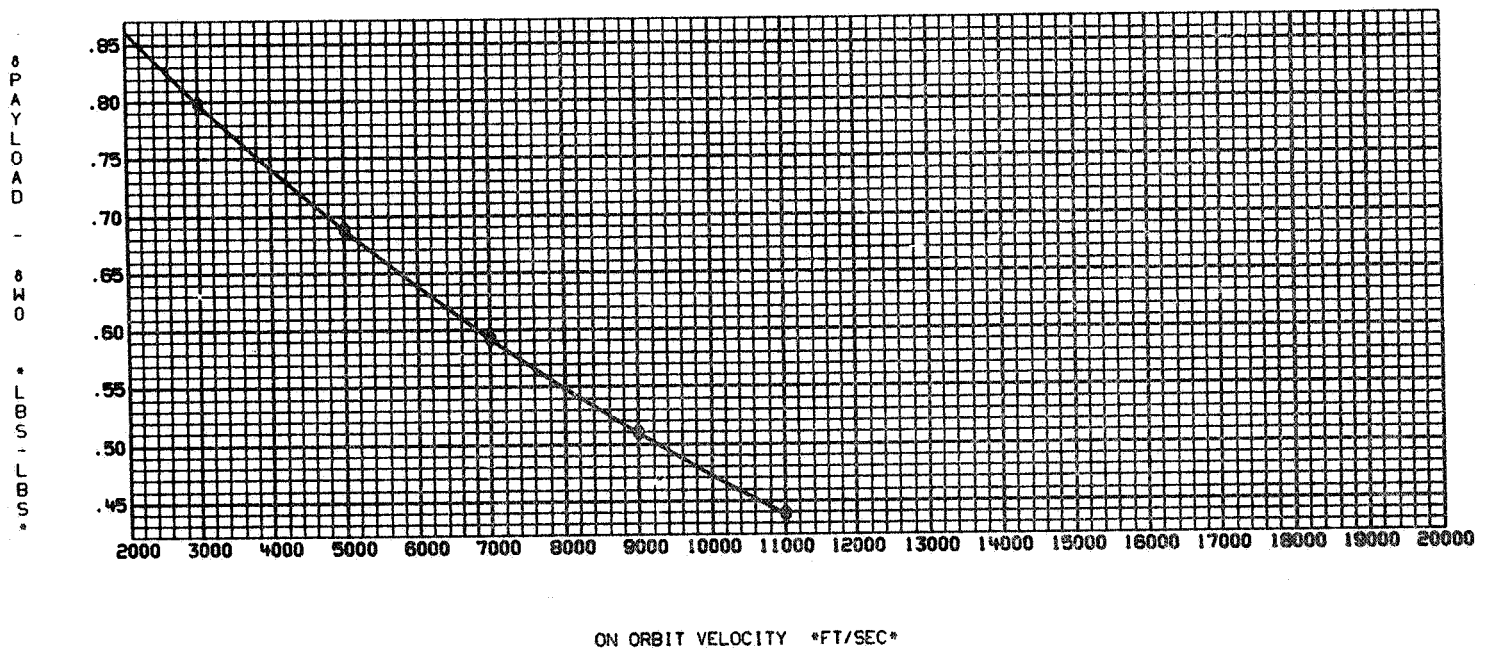


Figure 3-140

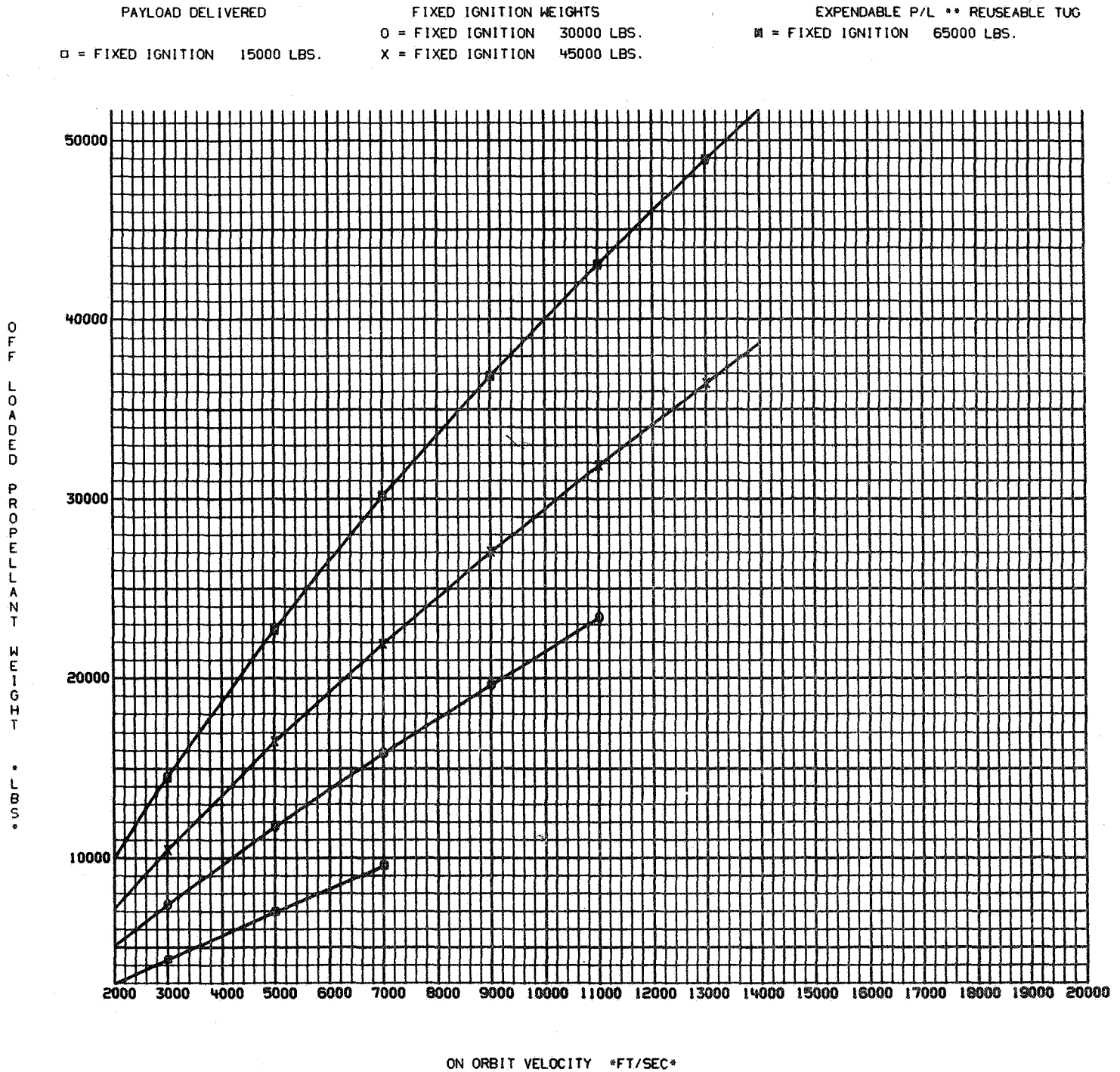


Figure 3-141

MODE 4

PAYLOAD DELIVERED		51994 LBS. FIXED PROPELLANT WEIGHT	EXPENDABLE TUG AND P/L
• = FIXED PROPELLANT 51994 LBS.		O = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
□ = FIXED IGNITION 15000 LBS.		X = FIXED IGNITION 45000 LBS.	

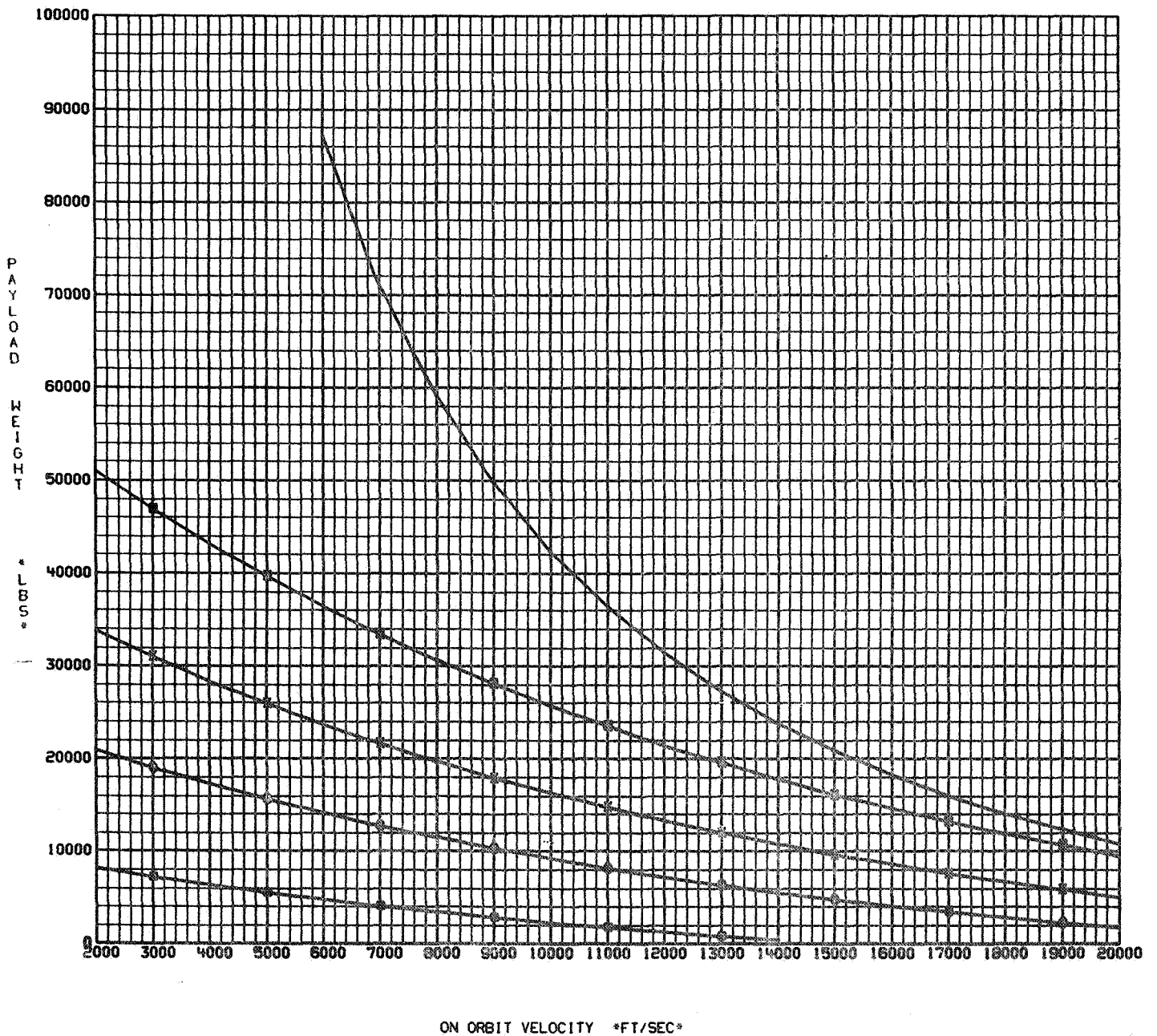


Figure 3-142

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT

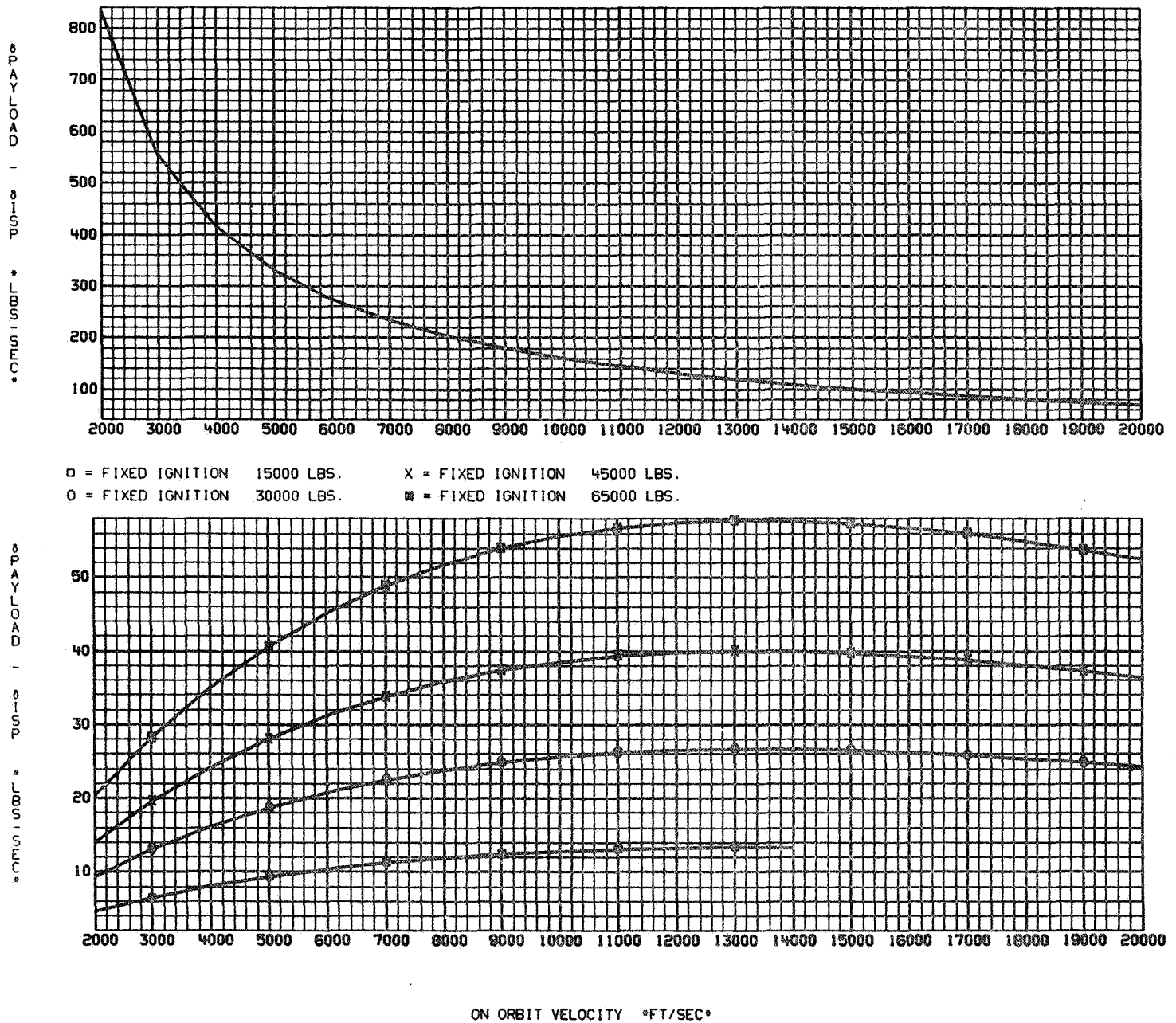
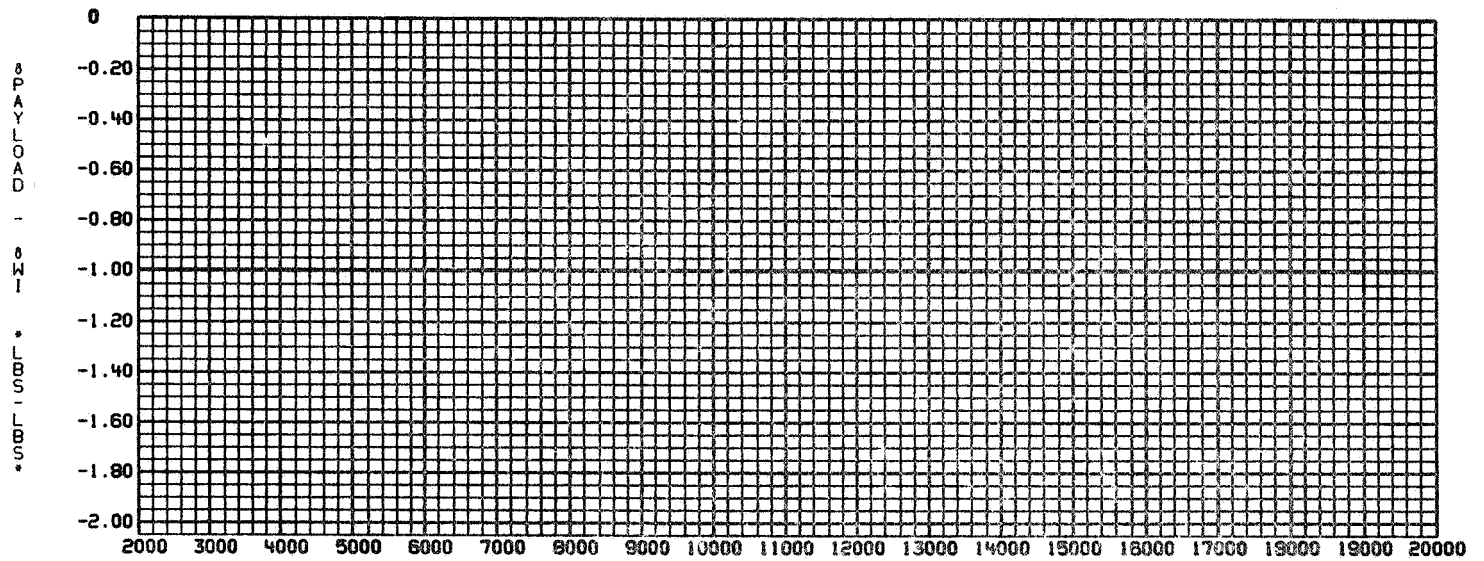


Figure 3-143

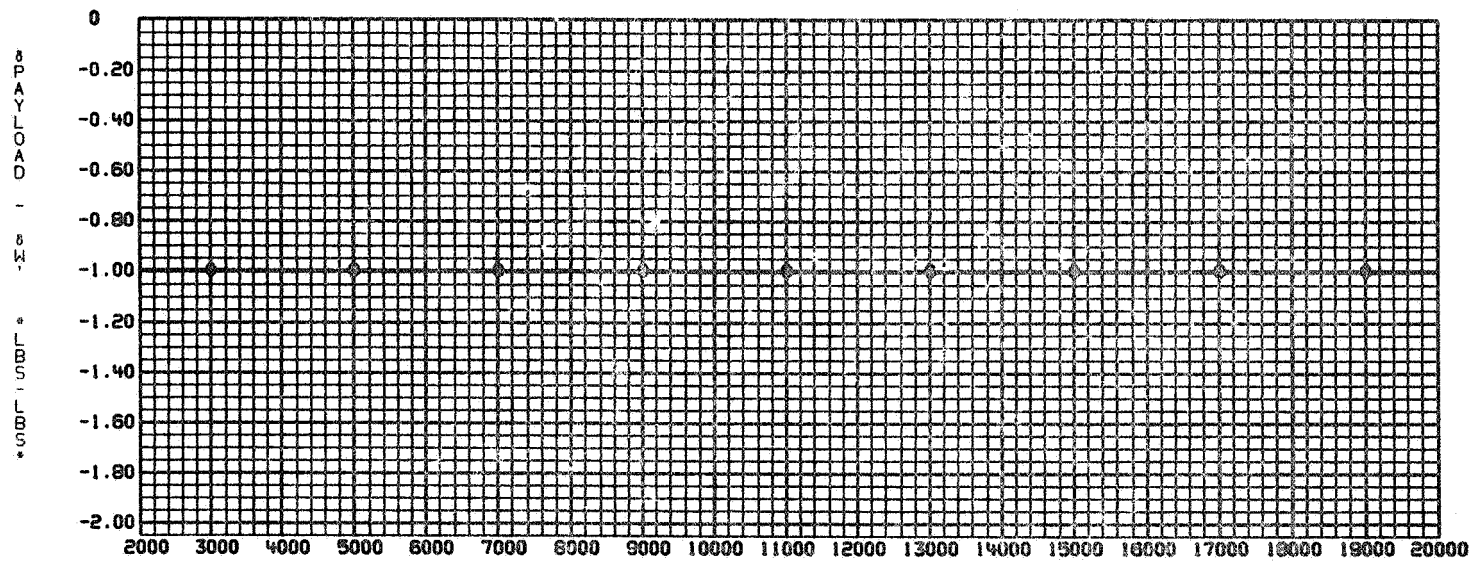
PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT



ALL FIXED IGNITION WEIGHTS



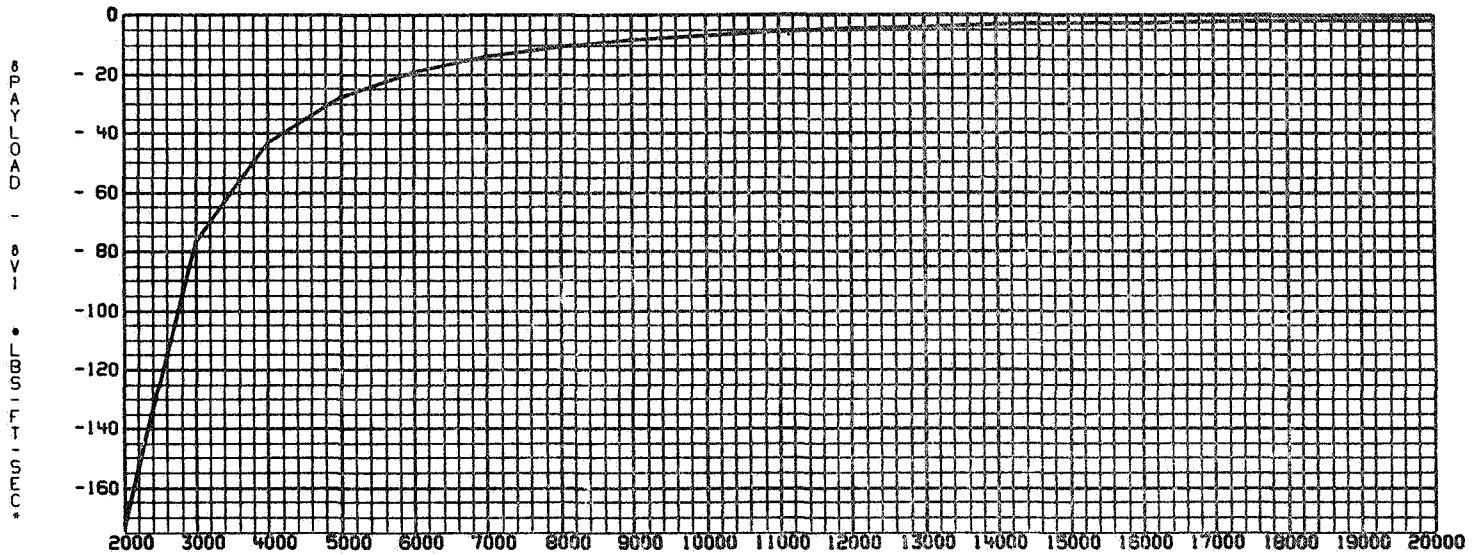
ON ORBIT VELOCITY *FT/SEC*

Figure 3-144

PAYLOAD DELIVERED

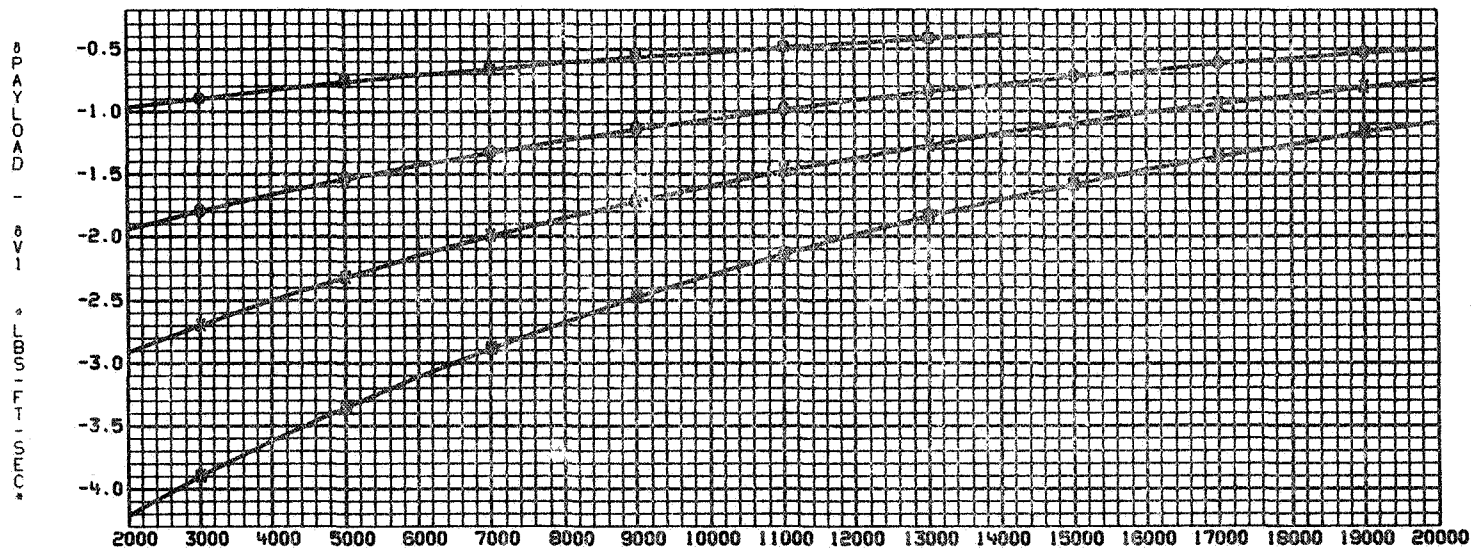
EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT



□ = FIXED IGNITION 15000 LBS.
○ = FIXED IGNITION 30000 LBS.

X = FIXED IGNITION 45000 LBS.
■ = FIXED IGNITION 65000 LBS.



ON ORBIT VELOCITY *FT/SEC*

Figure 3-145

PAYLOAD DELIVERED

EXPENDABLE TUG AND P/L

51994 LBS. FIXED PROPELLANT WEIGHT

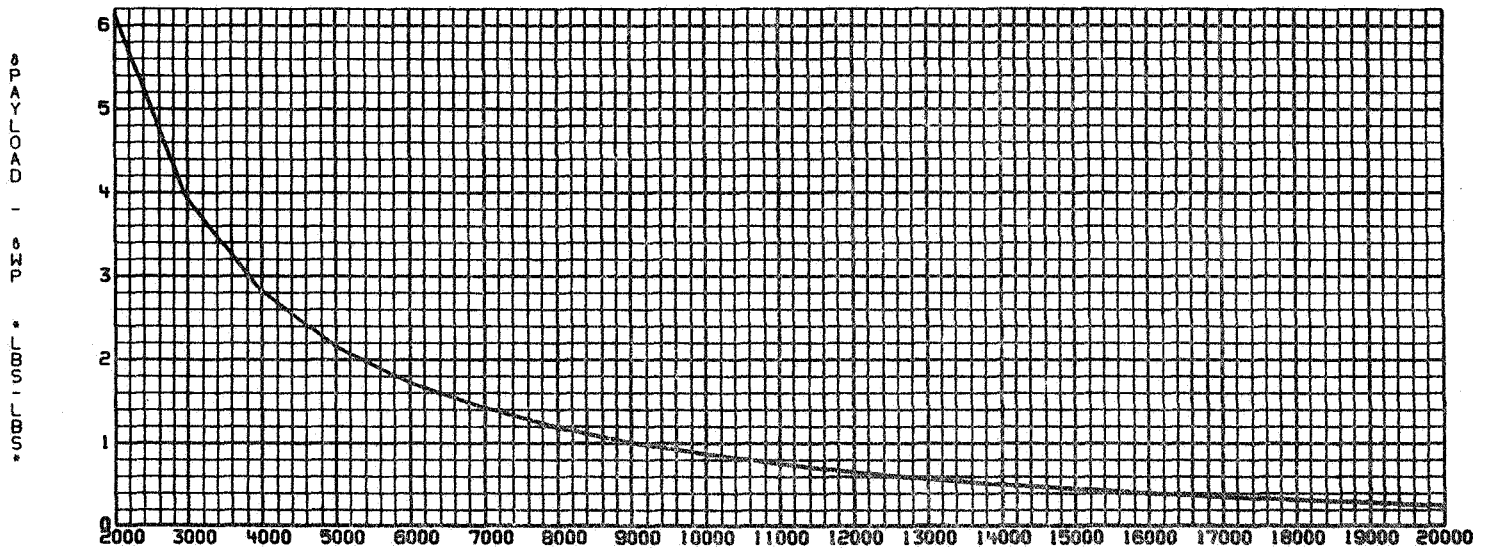


Figure 3-146

ALL FIXED IGNITION WEIGHTS

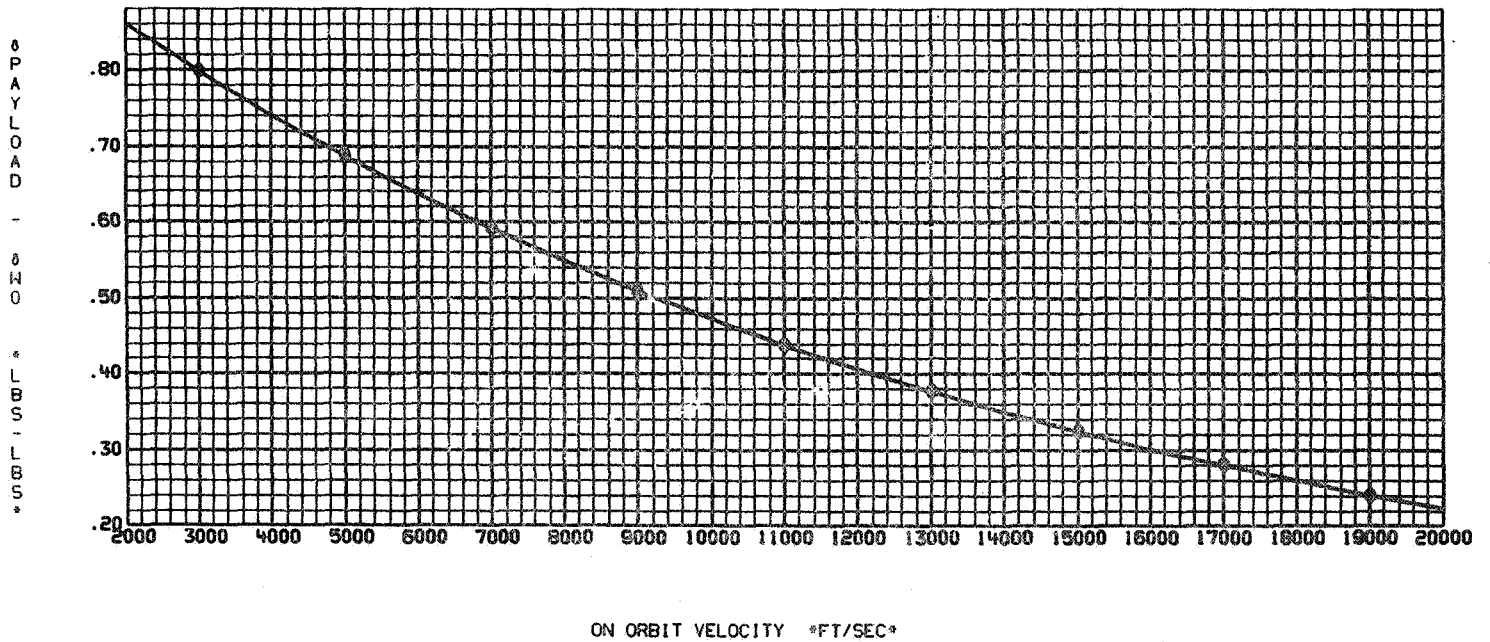


Figure 3-147

PAYLOAD DELIVERED	FIXED IGNITION WEIGHTS	EXPENDABLE TUG AND P/L
□ = FIXED IGNITION 15000 LBS.	○ = FIXED IGNITION 30000 LBS.	■ = FIXED IGNITION 65000 LBS.
	X = FIXED IGNITION 45000 LBS.	

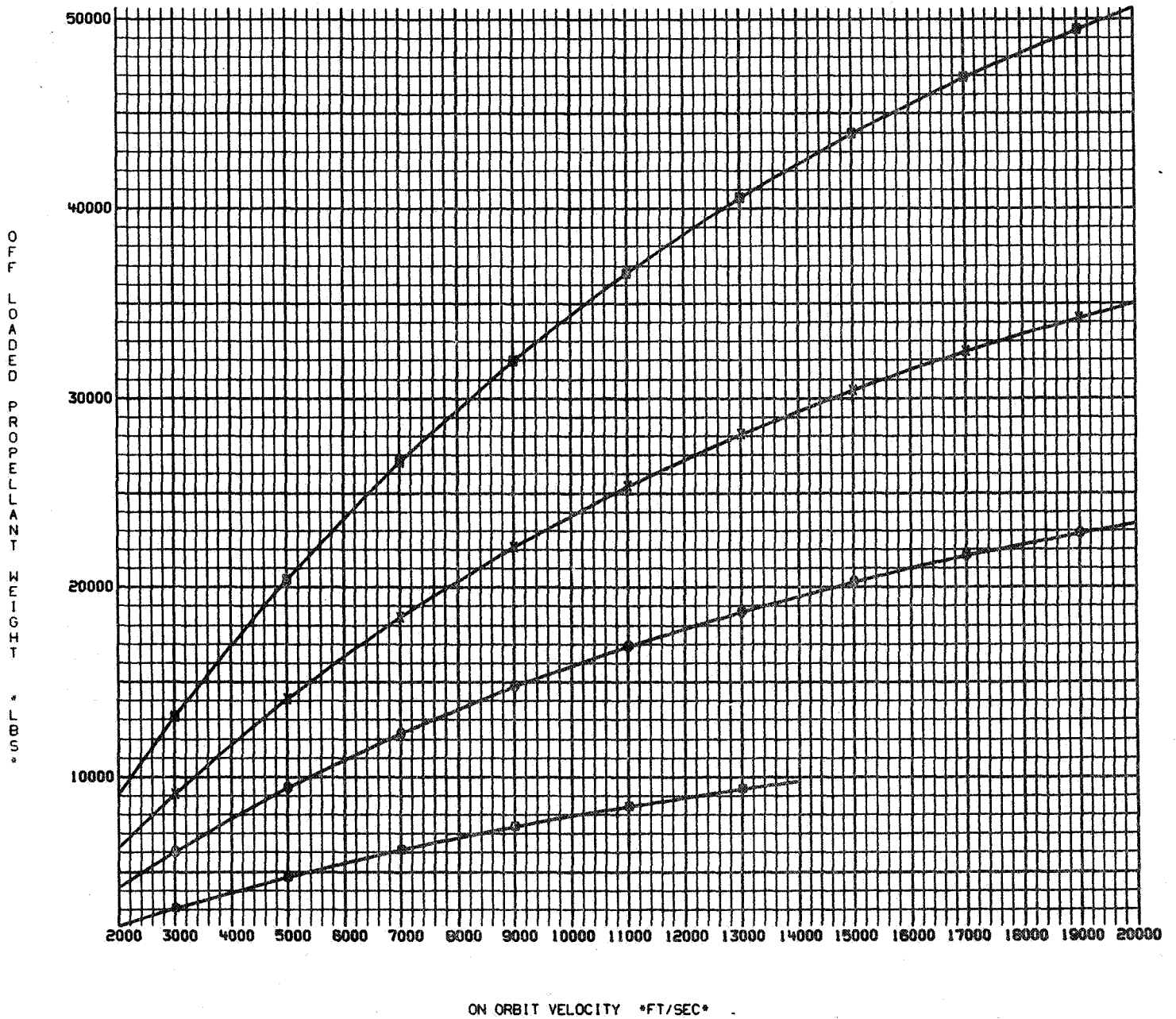


Figure 3-148